

UNCLASSIFIED

AD NUMBER	
AD032532	
CLASSIFICATION CHANGES	
TO:	unclassified
FROM:	secret
LIMITATION CHANGES	
TO: Approved for public release, distribution unlimited	
FROM: Distribution authorized to DoD only; Administrative/Operational Use; 01 MAY 1953. Other requests shall be referred to Office of the Chief Signal Officer, Army Signal Corps, Washington, DC. Pre-dates formal DoD distribution statements. Treat as DoD only.	
AUTHORITY	
D/A ltr dtd 11 May 1979; D/A ltr dtd 11 May 1979	

THIS PAGE IS UNCLASSIFIED

Armed Services Technical Information Agency

AD

32532

NOTICE: WHEN GOVERNMENT OR OTHER DRAWINGS, SPECIFICATIONS OR OTHER DATA ARE USED FOR ANY PURPOSE OTHER THAN IN CONNECTION WITH A DEFINITELY RELATED GOVERNMENT PROCUREMENT OPERATION, THE U. S. GOVERNMENT THEREBY INCURS NO RESPONSIBILITY, NOR ANY OBLIGATION WHATSOEVER; AND THE FACT THAT THE GOVERNMENT MAY HAVE FORMULATED, FURNISHED, OR IN ANY WAY SUPPLIED THE SAID DRAWINGS, SPECIFICATIONS, OR OTHER DATA IS NOT TO BE REGARDED BY IMPLICATION OR OTHERWISE AS IN ANY MANNER LICENSING THE HOLDER OR ANY OTHER PERSON OR CORPORATION, OR CONVEYING ANY RIGHTS OR PERMISSION TO MANUFACTURE, USE OR SELL ANY PATENTED INVENTION THAT MAY IN ANY WAY BE RELATED THERETO.

Reproduced by
DOCUMENT SERVICE CENTER
KNOTT BUILDING, DAYTON, 2, OHIO

**NOTICE: THIS DOCUMENT CONTAINS INFORMATION AFFECTING THE
NATIONAL DEFENSE OF THE UNITED STATES WITHIN THE MEANING
OF THE ESPIONAGE LAWS, TITLE 18, U.S.C., SECTIONS 793 and 794.
THE TRANSMISSION OR THE REVELATION OF ITS CONTENTS IN
ANY MANNER TO AN UNAUTHORIZED PERSON IS PROHIBITED BY LAW.**

Reproduced
FROM LOW CONTRAST COPY.

AD NO 32532

ASTA FILE CO

TEOTA REPORT

"THE EYES OF THE ARMY"



PROBLEMS OF BATTLEFIELD SURVEILLANCE

1 MAY 1953

This document contains information affecting the national defense of the United States within the meaning of the Espionage Act, 18 U. S. C., Sec. 793 and 794. Its transmission or the revelation of its contents in any manner to an unauthorized person is prohibited by law.

PROJECT TEOTA

OFFICE OF THE CHIEF SIGNAL OFFICER

Best Available Copy

Security Information

SECURITY INFORMATION

TEOTA REPORT

"The Eyes of the Army"

PROBLEMS OF

BATTLEFIELD SURVEILLANCE

1 May 1953

Edited by:

Mr. S. E. Clements, Syracuse University
Dr. S. Seely, Syracuse University
Col. F. F. Uhrhane, Office of Chief Signal Officer

Project TEOTA

Office of the Chief Signal Officer

SECURITY INFORMATION

SECRET
SECURITY INFORMATION

TABLE OF CONTENTS

	Foreword
Chapter 1	Introduction
Chapter 2	Systems
2.1	<u>Introduction</u>
2.11	Specific Army Organizational Elements
2.2	<u>A Company System</u>
2.21	Photographic System
2.22	Offensive Items - day
2.23	Offensive Items - night
2.24	Night Defense Items
2.25	Communications and Navigational Systems
2.3	<u>A Regimental Combat Team System</u>
2.31	Direct Support Artillery System
2.32	Reconnaissance in Depth
2.321	Acoustic System
2.322	TV System
2.33	Photographic System
2.34	Position Locating System
2.341	Radar Type
2.4	<u>A Field Army System</u>
2.41	Depth Problem, General Considerations
2.411	Guided Missiles
2.412	Field Army Surveillance Devices
2.42	Photographic System
2.43	Alarm and Detection System
2.431	Acoustic System
2.44	Target Location Methods
2.441	Good Weather
2.442	Bad Weather
2.443	280 mm. Gun and SSM Problem
2.444	Enemy Missile Activity Detection System
2.45	Proposed Prototype System
2.46	Operational Analysis
Chapter 3	Photography
3.1	<u>Introduction</u>
3.2	<u>Cameras</u>
3.3	<u>Vehicles</u>
3.4	<u>Illuminants</u>
3.5	<u>Processing</u>
3.51	Land-Polaroid Process
3.52	Electrostatic Photography
3.53	Kodak Development Film
3.54	Kodak Processing System
3.55	Mobile Processing Laboratory
3.56	Multiple Prints

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

-2-

- Chapter 3 Photography (continued)
- 3.6 Transmission
 - 3.7 Interpretation
 - 3.8 Conclusions
 - 3.9 Recommendations
- Chapter 4 Radar
- 4.1 Introduction
 - 4.2 Radar Techniques
 - 4.21 Detail Structure
 - 4.22 Variations with Time: Moving Target Techniques
 - 4.23 Gradations in Amplitude
 - 4.24 Multiple Channels
 - 4.25 Polarization Characteristics
 - 4.26 Variations with Aspect Angle
 - 4.27 Variation with Frequency
 - 4.28 Passive Microwave Detection
 - 4.3 Radar Devices and Programs
 - 4.31 Personnel Detection
 - 4.311 AN/FPS-L
 - 4.312 Butterfly Type Equipment
 - 4.313 Cross-Correlation Type of System
 - 4.32 Mortar Location
 - 4.321 AN/MPQ-10
 - 4.322 AN/MPQ-7
 - 4.323 AN/MPQ-4
 - 4.324 AN/KPQ-1
 - 4.33 Machine Gun and Small Arms
 - 4.34 Artillery Location
 - 4.341 AN/TPQ-5 (XE-1)
 - 4.342 AN/MPQ-21 (XE-1)
 - 4.343 Modification of AN/MPQ-10
 - 4.35 Moving Vehicle Detection
 - 4.36 Weather
 - 4.37 Airborne Surveillance
 - 4.371 Area Surveillance
 - 4.372 Spot Surveillance
 - 4.373 Motion Surveillance
 - 4.4 Proposed Program
 - 4.41 Ground-based Problems
 - 4.42 Airborne Systems
 - 4.43 Techniques for Identification
- Chapter 5 Photo-Electric Systems
- 5.1 Introduction
 - 5.2 Systems and Special Components
 - 5.21 Portable Television System for the Infantry
 - 5.22 Helicopter Television Mortar Locator System

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

-3-

Chapter 5

Photo-Electric Systems (continued)

- 5.23 Television Reconnaissance from Drone Aircraft
- 5.24 Rocket Reconnaissance System
- 5.25 Tank Television System
- 5.26 Storage Camera Tube Development
- 5.27 High Resolution Camera Tube and Optics
- 5.28 Multi-Lens Optical Development

5.3 Contemporary State of the Art

- 5.31 Military television Projects and Equipments
either used in or directly applicable for use
in reconnaissance systems.
 - 5.311 Signal Corps Program (Coles Signal Laboratory)
 - 5.312 Air Forces Program as Related to Reconnaissance
 - 5.313 Navy Television Programs
 - 5.314 Developments in Completely Portable Television
Equipment
- 5.32 Related Developments
 - 5.321 Television Systems
 - 5.322 Storage Tube Developments
 - 5.323 Infrared Pickup Tube Developments
 - 5.324 Miscellaneous Developments
- 5.33 Battlefield Illuminants

5.4 Recommendations and Discussion

- 5.41 Portable TV System for Infantry
- 5.42 Helicopter Television Mortar Locator System
- 5.43 Television Reconnaissance from Drone Aircraft
- 5.44 Rocket Reconnaissance System
- 5.45 Storage Camera Tube Development
- 5.46 High Resolution Camera Tube and Optics
- 5.47 Color Television for Reconnaissance

5.5 Summary of Recommendations

Chapter 6

Infrared

6.1 Introduction

6.2 Infrared Techniques

- 6.21 Classification
- 6.22 Imaging Devices
 - 6.221 Image Tube (Near Infrared Region)
 - 6.222 The Infrared Image Orthicon
 - 6.223 The Brightness Intensifier
 - 6.224 Intermediate Infrared Imaging (1956-60)
 - 6.225 Far Infrared Imaging
 - 6.226 Passive Photo-Emission Viewers
- 6.23 Point by Point Response Detectors
 - 6.231 General Considerations
 - 6.232 Threshold of Sensitivity or Noise Equivalent
Power

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

-4-

Chapter 6

Infrared (continued)

- 6.233 Frequency Characteristics or Time Constant of the Cell
- 6.234 Passive Microwave Detection
- 6.3 Infrared and the Battlefield Surveillance Problem
 - 6.31 Range: 0 to 300 yards
 - 6.311 Near Infrared Viewing Devices Utilizing the Image Tube
 - 6.312 The Evaporograph
 - 6.313 Brightness Intensifier
 - 6.314 Penrod and Scanrod
 - 6.315 AN/PAS-2
 - 6.316 Passive Sighting Devices
 - 6.317 Integrated Radar - Infrared Target Identification Set
 - 6.318 Warning Devices to Foot-Soldier
 - 6.319 Infrared Image Orthicon
 - 6.32 Range: 300 - 3,000 yards
 - 6.321 Flash Ranging
 - 6.322 Identification Systems
 - 6.323 Possible Future Developments
 - 6.324 Surveying Systems
 - 6.33 Range: 0-200 miles
 - 6.331 Thermal Reconnaissance Device (TRD)
 - 6.332 Infrared Detector Sets AN/AAS-1(XA-2) and AN/AAS-1(XA-3)
 - 6.333 Developments 1954-56 period
 - 6.334 Developments 1956-60 period
 - 6.335 Navigational Aids
- 6.4 Infrared Communication Systems
- 6.5 Infrared Gas Analyzers
- 6.6 Conclusions and Recommendations
 - 6.61 Conclusions
 - 6.62 Recommendations
 - 6.621 General Recommendations
 - 6.622 Specific Recommendations

Chapter 7

Acoustics

- 7.1 Introduction
- 7.2 Ranging of Enemy Sources by Airborne Sound
- 7.3 Seismic Methods
- 7.4 Identification of Enemy Sound Sources
 - 7.41 Bell Telephone Laboratories
 - 7.42 National Bureau of Standards
- 7.5 Remote Sonic or Seismic Detection Devices
- 7.6 Sound Propagation in Air
- 7.7 Recommendations

SECRET
SECURITY INFORMATION

Chapter 8

Weather

8.1 Introduction

8.2 Weather Techniques

8.21 Conventional Weather and Auxiliary Observations

8.211 Conventional Weather Equipment Currently in Use

8.212 Recently Developed Equipment in Procurement Stages

8.213 New Equipment Under Development

8.214 Proposed Developments

8.2141 Autosonde

8.2142 Coptersonde

8.2143 Parachute Automatic Weather Stations
SCM-18 and AN/GMP-1

8.2144 Transosonde

8.2145 Light Aircraft Weather Equipment

8.22 Radar Weather Observations

8.23 Weather Forecasting

8.231 Local Weather Analysis

8.232 Broad-scale Weather Analysis

8.233 Local Weather Prognosis

8.24 Weather Control

8.241 Cloud Dissipation

8.242 Fog Dissipation

8.243 Artificially Induced Precipitation

8.244 Thunderstorm Modification

8.245 Artificially Created Clouds

8.246 Artificial Illumination of the Battlefield

8.25 Direct Detection of Enemy by Atmospheric Effects

8.251 Atmospheric Ionization

8.252 Nuclei Detection

8.3 Recommendations

8.31 Immediate (0-2 years)

8.311 Personnel

8.312 Equipment

8.313 Communications

8.32 Intermediate (2-4 years)

8.321 Equipment Development

8.322 Weather Control

8.33 Future (4-8 years)

8.331 Equipment Development

8.332 Atmospheric Detection of Enemy

Chapter 9

Vehicles

9.1 Introduction

9.2 Factors Affecting the Choice of Vehicles

9.21 Vehicle Requirements

9.211 Type A Requirement for Vehicles

9.212 Type B Requirements for Vehicles

- Chapter 9 Vehicles (continued)
- 9.22 Vehicle Vulnerability
 - 9.221 Detectability
 - 9.222 Size Effect - Vulnerable Area
 - 9.223 Velocity Effect
 - 9.224 Altitude Effect
 - 9.3 Promising Vehicle Types
 - 9.31 Vertical Rising Aircraft
 - 9.32 Fighter Type
 - 9.33 Airborne Relay Station
 - 9.34 Small Liaison Airplane
 - 9.35 Small Drone Helicopter
 - 9.36 General Purpose Helicopter
 - 9.37 Artillery Shells, Rockets, Bazookas-Short Range
 - 9.38 Small Expandable Missile-Short Range
 - 9.39 Long-Range High Subsonic Missiles
 - 9.310 Target Drone Airplanes
 - 9.311 Weapon Carrying Drones
 - 9.312 Balloons
 - 9.313 Man as a Vehicle
 - 9.314 Ground Vehicles
 - 9.4 Vehicle Selection
 - 9.41 Vehicle Cost
 - 9.42 Basis of Air Vehicle Selection of Table II -
Second Approximation
 - 9.5 Conclusions
- Chapter 10 Navigation, Control and Guidance
- 10.1 Introduction
 - 10.11 Basic Methods of Locating Targets
 - 10.12 Required Position Determination Accuracy
 - 10.13 Portability
 - 10.14 Equipment Location
 - 10.15 Distance Considerations
 - 10.16 Control
 - 10.2 Artificial Landmarks
 - 10.21 Marker Characteristics
 - 10.22 Marker Types
 - 10.23 Placing and Surveying the Landmarks
 - 10.3 Aids to Navigation
 - 10.31 Electromagnetic Systems
 - 10.32 Other Aids to Navigation
 - 10.33 Auxiliary Devices
 - 10.4 Control
 - 10.41 Program
 - 10.42 Command
 - 10.5 Conclusions
 - 10.51 Landmarks

SECRET
SECURITY INFORMATION

-7-

- Chapter 10 Navigation, Control and Guidance (continued)
- 10.52 Electromagnetic Aids
 - 10.53 Self-Contained and Other Aids
 - 10.54 Auxiliaries
 - 10.55 Control
 - 10.6 Recommendations
 - 10.61 1952-1954
 - 10.62 1954-1956
 - 10.63 1956-1958
- Chapter 11 Communications and Data Transmission
- 11.1 Introduction
 - 11.2 Systems Considerations
 - 11.3 Communication Techniques
 - 11.31 Vehicle Circuits
 - 11.32 Distribution Circuits
 - 11.33 Short Range Communication
 - 11.34 Security and Intercept Analysis
 - 11.4 Data Transmission, State of the Art
 - 11.5 Recommendations
 - 11.51 Short Period Programs
 - 11.52 Long Period Program (3-5 years)
- Chapter 12 Other Methods and Problems
- 12.1 Introduction
 - 12.2 Visual
 - 12.21 Project TACIT
 - 12.22 BEACON HILL Report
 - 12.23 Recommendations
 - 12.3 Magnetic Techniques
 - 12.31 The Earth's Magnetic Field
 - 12.32 Conclusions
 - 12.33 Recommendations
 - 12.4 Detection of Combustion Products
 - 12.41 Navy Experiments
 - 12.42 Density of Combustion Components in the Atmosphere
 - 12.43 Recommendations
 - 12.5 Field Experiments on Military Equipment
 - 12.51 Amplitude versus Frequency Spectra
 - 12.52 Conclusions
 - 12.53 Recommendations

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

FOREWORD

Project TEOTA, "The Eyes of The Army" is a study project on the technical aspects of battlefield surveillance. It is the result of a directive to the Chief Signal Officer from the Assistant Chief of Staff for Logistics, G-4, Army, during August 1952 following a series of letters on airborne television systems. The Signal Corps Research and Development Advisory Council under the guidance of Dr. W. R. G. Baker proposed a plan of action which would establish a temporary study group consisting of nine technical panels, covering major technical fields and a secretariat. This group was organized by the Chief Signal Officer, and the panels, each composed of scientific and engineering experts, prepared detailed technical reports pertaining to their respective fields. These individual reports were reviewed and consolidated into this summary report by the secretariat.

Technical panels were organized for each of major scientific fields bearing on the problem, namely:

Radar
Infrared
Acoustics
Photography
Weather
Photo-electric Systems
Communications - Data Transmission
Vehicles
Guidance and Control

Over 100 individuals took an active part in Project TEOTA by working on panels or the secretariat. About 45% came from industry, 45% from government, and 10% from educational institutions. The U. S. Navy, the U. S. Air Forces and the other Technical Services of the Army

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

-2-

contributed personnel for the panels, as well as making available technical reports and files for the study. Acknowledgement is made to the National Bureau of Standards for the services of a group of scientists of the Corona Laboratory and for the office space used by the secretariat. Considerable assistance was received from members of the staff of the Research and Development Board, from Project TACIT of the Operational Research Office, Johns Hopkins University, and from several senior Army officers with combat experience who participated in the discussions of several panels. The Project personnel are listed by name and affiliation in Appendix 1.

Three recent studies under the sponsorship of the Armed Forces were used extensively as background material for this project and for assistance in planning the work and the report. These studies were Project VISTA, Project BEACON HILL, and Project CHARLES:

a. Project VISTA was undertaken by a group assembled by the California Institute of Technology under Army sponsorship to study some of the problems of ground and air tactical warfare, especially as related to the defense of Western Europe in the immediate future. The final report issued 4 Feb. 52 included a very broad consideration of military tactics and equipment.

b. Project BEACON HILL was undertaken by a group assembled at the Massachusetts Institute of Technology under sponsorship of the U. S. Air Force, with the report being dated 2 June 1952. This project was concerned with the problem of air reconnaissance, both tactical

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

-3-

and strategic, with principal attention to the latter.

c. Project CHARLES was also performed at M.I.T. by a task group under the sponsorship of the armed services Joint Service contract. This project was an investigation of the general problem of defense against air attack, with special attention to the defense of North America.

While the prior projects and other activity bear considerably on the problems investigated in the present study, Project TEOTA represents completion of the first comprehensive, convergent effort in the area of battlefield surveillance for ground troops. It is believed appropriate to reiterate the points so well stated in the report on Project VISTA in connection with their particular problem. These points are valid for Project TEOTA, as for other projects with survey aspects.

The VISTA Report states in part:

"In presenting this report we wish to make it clear that we do not claim full originality either for the data presented or for most of the conclusions reached and recommendations made. Of necessity, most all of the material we have obtained has come from the military departments or from their contractors or consultants. Our major role has been to bring together in one place and in a highly condensed form that part of the information which seems pertinent to our assigned problem. We are aware that we have not achieved a complete compilation of all that is known in this field and, indeed, that we can present only a partial summary of the vast volume of information that has been made available to us.

Many of our conclusions and recommendations will have a familiar sound to members of the military departments. Some of those consulted have helped us reach them. Recommendations similar to ours have been noted in official documents."

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

-4-

This report includes an introductory chapter (Chapter I) which contains a statement of the problem, a discussion of the assumptions used in the study, and a consideration of general principles which apply to the study. (A consideration of the systems aspects of the problem follows). The bulk of the report consists of ten chapters based on the studies and recommendations prepared by the separate technical panels. A series of TEOTA recommendations containing details of specific proposals or otherwise supplementing the technical chapters are referred to in the text of the report. These are not reproduced, but are on file in the appropriate office in the Office of the Chief Signal Officer.

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

CHAPTER I

INTRODUCTION

The combat effectiveness of the individual soldier depends in very high degree upon his knowledge of the enemy. This dependence is greatest when he is outnumbered on the battlefield. Then it becomes absolutely mandatory that he be able to sense the enemy's dispositions. Leaving aside any consideration of victory, the soldier's very survival depends upon the degree to which he is able to read the map of opposing forces. His natural tools for acquiring much information have become less and less adequate as the complexity of warfare has gradually increased through the years. This very complexity tends to be regenerative and its ultimate effect is to bring about an ever increasing need for rapid and continuous surveillance of the battlefield to provide more and more up to date information. Such information, together with considerations of the commander's own forces and objectives, becomes the basis for command decisions and subsequent action. In the field, the information must be available at a number of command levels in varying degrees of detail. At the present, combat commanders have intelligence requirements which are not being met by techniques now used. The existence of the problem is well known from campaign studies of World War II and the Korean War. It is apparent that the situation has become further aggravated since World War II by the development of new weapons in the fields of guided missiles and atomic artillery.

The intelligence requirements of the various combat units are, in

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

1-2

general, dependent on the weapons and the typical missions of those units. The essential elements of information are those pertaining to the enemy and those pertaining to terrain features, terrain conditions and the weather. Information pertaining to the enemy includes not only target acquisition data for the direct use of weapons, but all information bearing on enemy capabilities. Generally combat intelligence is concerned with the objective consideration of enemy capabilities rather than with what can be guessed concerning the enemy intentions, in order that the commander may prepare to deal with whatever the enemy is capable of doing.

In order to achieve complete battlefield coverage, every space element of the battlefield would have to be surveyed during every moment of time. Such coverage, even if technically attainable, would produce such a mass of information that communications and interpretation procedures cannot be visualized which would sort out the essential elements of information. Furthermore, a technical effort to accomplish complete coverage would lead to complexity which would be prohibitive in terms of manpower required for development and field usage. It is therefore necessary to evolve patterns of surveillance whose complexity are related to the actual requirements of particular combat situations and to practical operability in terms of battlefield organization. An evaluation of all known methods in the light of their relative effectiveness, complexity, influence on military logistics and tactics is required. From this, a particular method or group of methods holding greatest

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

1-3

promise might be selected and adopted for specific tactical problems, thereby evolving an overall surveillance system.

This study is concerned mainly with the acquisition of battlefield intelligence by the employment of sensing means based on the physical sciences. No consideration has been given to the acquisition of intelligence from such sources as prisoners of war, deserters, covert agents, and documents. It is assumed that all such available sources will be exploited, and that information from such sources will be correlated with that from physical sensing devices in the intelligence procedure by the combat unit staff. It is apparent that data interpretation and data presentation techniques must be developed in pace with the development of sensing equipment, so that the essential elements of information are appropriately presented to the commander for consideration in making decisions. It is also apparent that substantial gains can be made in effectiveness of the intelligence process by research and development in these fields, as well as in the field of physical sensing devices. This study has only concerned itself with those aspects of data interpretation and presentation which are closely associated with individual techniques or equipments. It has not explored the overall problem of intelligence interpretation and presentation.

In order to define the battlefield surveillance problem, consideration is required of the weapons, missions, and individual intelligence requirements of the various army elements. For purposes of simplifica-

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

1-4

tion, the infantry company, the regimental combat team, and the field army will be discussed. In addition the special problem of intelligence for utilization of tactical atomic weapons will be outlined.

The infantry company has a limited tactical objective, and is provided with such equipment and weapons as is deemed adequate for achieving the objective. Its weapons consist principally of small arms, mortars, and machine guns. Consequently the company's primary requirement is for sensing devices which will yield the information concerning the location of enemy units against which the company can effectively use these weapons. Moreover, the packaging of such sensing devices must be such as to permit transportation by man-pack. Equipment must be portable, and of light weight; it must yield information quickly; it must provide the information in a form readily usable by the infantryman.

The essential company problems are, therefore:

- a. Personnel detection at relatively short range.
- b. Mortar location for the infantry.
- c. Machine gun and small arms location.
- d. Detection and location of tanks or other vehicles at short range.
- e. Location of and communication with our elements and patrols.

Although intermediate units exist between the infantry company and the Regimental Combat Team, the requirements of these intermediate elements are still basically those of the company. The objectives of

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

1-5

the regimental combat team are more extensive. It requires a wider assortment of weapons, with the attendant requirements for extensive information in order to employ these weapons most effectively. Also, owing to its size, the combat team can tolerate equipment that is larger and heavier than that for company use. Correspondingly, however, it requires higher performance equipment. Among its requirements are:

- a. Personnel detection at short range.
- b. Detection of personnel masses at relatively remote points who might be brought up rapidly for action (10 to 25 miles).
- c. Mortar location (2-3 miles).
- d. Artillery location (10 miles).
- e. Location of vehicles and vehicle concentrations, including trucks, tanks, weapon carriers, etc. (10-25 miles).

The Field Army has responsibilities beyond those of the Combat Team, and in addition to the requirements listed above, its surveillance needs extend several hundred miles behind the enemy lines. Among its interests, in addition to locations of personnel masses, are such items as: armored units, ground concentration of aircraft; missile concentrations and launching sites; supply depots, bridges, etc.

The special problem of intelligence for tactical atomic weapons arises from the newness of this class of weapons and the relatively high cost of each firing. The lack of prior availability means a lack of experience and a firm doctrine of employment to serve as a guide in planning the intelligence system. The economic cost of each firing indicates a need for certainty of the existence of a suitable target

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

1-6

beyond that normally required for other weapons. Due to the large radius of effectiveness of the individual atomic explosion, accuracy of target location is not quite so critical a requirement as for a conventional shell.

It is assumed that a proper tactical atomic target is a mass concentration of troops and weapons. There is then a requirement for the early discovery of the existence, general location, and size of a build-up. From such information there is made a decision as to whether or not an atomic target exists. If the decision is affirmative, there is a requirement for the location of the most profitable aiming point.

As a corollary, it must be assumed that the use of tactical atomic weapons will alter very quickly the pattern of enemy dispositions within the area in which such weapons are threatened. The tendency will doubtless be toward more disperse formations and greater use of darkness or bad weather for major troop movements and concentrations. The net result should be to make the search for profitable targets for all kinds of weapons even more difficult than it is at present.

Physical sensing devices are effective through the mechanism of radiation or reflection from the objective and most of the applicable physical phenomena may be employed in either fashion. Utilization in active fashion requires a source of radiation directed toward the objective with subsequent detection of this radiation as reflected from the objective. Passive utilization involves only the employment of detection devices which are designed to intercept radiations generated

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

1-7

within or emanating from the objective itself. Generally the radiation detected in passive methods is energy which plays no functional military part in the performance of the material or personnel emitting it. It is therefore susceptible in some degree to local suppression or camouflage.

In the more refined methods of physical sensing, "fingerprints" or "signatures" of the various objectives may be detected, thereby enabling positive identification of the nature of the target. In other methods only changes to prior patterns are detected, so that identification must be made by deduction or by correlation with other information. Frequently identification can be made from such clues as speed and manner of movement, or from minor alteration in terrain features. In these cases one needs detection of the occurrence of a change, identification of the military cause of the change, and finally precise location of the agent which caused the change. No single physical phenomenon is adequate to give information on all enemy activity and related features of the battlefield. Although most physical phenomena can be used in either active or passive fashion, they all suffer from certain limitations with respect to weather or terrain conditions and most can be employed effectively against only a few types of targets.

For each physical phenomenon available for use in sensing devices this study therefore considers several factors. The first factor is the inherent limitation imposed by physical laws on the phenomenon under consideration. In those cases for which inherent limitation can

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

1-8

be described, the limitations form a boundary beyond which exploitation cannot proceed. In those cases in which current knowledge is insufficient to describe the inherent limitations, research is presumably in order to extend the existing knowledge and to formulate the physical laws. The second factor pertaining to each physical phenomenon is the limitation imposed by the present state of the art in the particular field. This part of the discussion gives an indication of performance which might be expected from employment of the phenomenon using components presently capable of being produced. It generally includes details of existing apparatus. Lastly, for each phenomenon under consideration there is a discussion of advances which are believed possible by research and development in the foreseeable future. Thus the probable future effectiveness attainable by the particular phenomenon in solving the military problem is evaluated in such a fashion as to guide the preparation of a detailed research and development program. For purposes of this study, three periods of time have been arbitrarily defined: present to 1954, 1954-56, and 1956-60. In each instance the time of availability of prototype devices for extended field test is used to determine the time period of availability of the equipment, so as to avoid considerations of time required for acceptance testing and for quantity production.

In addition to the study of physical sensing means, three categories of accessories to sensing devices have been considered, namely, vehicles, navigation systems, and communications and data transmission schemes.

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

1-9

Most of the sensing means are of limited range and the enemy may be hidden behind hills or beyond the horizon. Thus a vehicle is required to carry the sensing means within range of the enemy. In its most fundamental form the vehicle is the soldier. Some devices must be flown in aircraft or missiles to be within operating range of the enemy, others may be planted by air drop or by artillery shell fired from conventional weapons. Since location is an essential element of military information, sensing devices and reconnaissance vehicles must incorporate or must operate in conjunction with some navigation scheme which will provide location coordinates. Therefore, a study of navigation systems has been made. Likewise a communication link is required in order to handle the information from the sensing device to the ultimate user. In many cases the modes and form of transmission will be determined by the nature of the sensing device and the vehicle. However, some general considerations apply. For the most part, it has been assumed that the communications systems and techniques as applicable to the tactical units for other purposes will be suitable for the transmission of intelligence after it has entered the intelligence network. It is believed that specialized methods generally will be required from the sensing device back to the first human being.

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

CHAPTER 2

SYSTEMS

2.1 Introduction:

A system is an aggregate of individuals and equipments which perform collectively and by interrelated actions an important function. It is contrasted with individual equipments or persons, each of which may have an important purpose. In broad terms, the intelligence system includes all forms of data collection, collation, interpretation, transmission, and presentation. As discussed in Chapter 1, Project TEOTA has been limited to data collection by physical sensing techniques. "System" as used here will indicate a sensing system to perform limited reconnaissance against specific targets and generally for a particular army organizational element. The sensing system will include sensing devices, communications and navigational features, some form of vehicle and a modus operandi.

Generally in systems engineering a concise statement of the problem and the assumptions made is a necessary first step in the system design. In the present situation, the broad requirements and assumptions are not well defined and, in fact, may be controversial. On the other hand economy of technical manpower and considerations of confusion and complexity emphasize the need for reducing TEOTA to a systems engineering pattern as rapidly as possible.

Enough of the parameters and limitations are even now apparent so that some rules of thumb can be formulated and speculations made.

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

2-2

In each case any conclusion must be assumed to be "subject to change without notice" as investigation uncovers new facts or as functions and missions are clarified or altered.

2.11 Specific army organizational elements have been chosen and their intelligence requirements reduced to those considered most pressing currently. Then a system has been postulated for each organization using only known techniques and equipments which are believed to be capable of development at the present time.

The army units selected are the company, the regimental combat team, and the field army. The bases of the selection have been criteria of mission, weapons, and transportation capability. The infantry company uses hand weapons, attains mobility on the battlefield by foot, is limited in transportation capability to what individual men will carry under battle conditions. The regimental combat team is the smallest unit normally combining the combatant arms, including artillery, has some vehicles for transportation and for the mobile elements. The field army generally possesses all weapons including atomic artillery; has tactical air capability through its associated Tactical Air Force; and has the most refined equipment, techniques and skilled men which are placed in the field. Also generally, the field army mission is such that the commander gives due regard to strategic considerations in action decisions which is in contrast to the company and regimental combat team commanders.

It must be constantly borne in mind that the above breakdown is

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

2-3

for ease in discussion of the problem; and that the company, the RCT, the field army are not separate entities each with its own problems independent of the others. The fighting force achieves results by effective action based on the coordinated use of all its components. Therefore, the requirements of the various elements tend to be overlapping, and flexibility is mandatory.

2.2 A Company System:

The infantry company surveillance problem appears to be principally one of location of enemy infantrymen. During periods of advance and attack, enemy strong points and their automatic weapons, i.e. machine guns, are of particular interest. Visual observations and deductions from terrain features and maps are normally used for attack planning purposes. For the attack itself primary and almost sole reliance has been on visual observation. For that reason attacks are usually planned for daylight hours. An improved night attack capability is desirable. Foul weather and conditions of low visibility present similar difficulties to night darkness, although in different degrees. During defense actions the principal requirement is apparently for means to counter enemy surprise attacks at night or in the early morning twilight after night assembly.

2.21 It is believed that the company attack planning task can be materially assisted by the use of rapid photography. In this connection, consideration should be given to the stereo technique and the use of a simple tower. Subsequently a night capability can be developed for this

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

2-4

photographic system by the development of suitable illuminating ammunition for company weapons, possibly in the form of rifle grenades or mortar shells; or by development of an artillery-infantry coordination procedure whereby the support 105 mm howitzers would fire the illuminants for the front-line photography.

2.22 During offensive fighting in the daytime, advancing individual soldiers use visual observation and are able to carry little equipment in addition to their weapons and ammunition. Enemy machine guns and mortars are of great concern at this time, and their location for counter action is of the greatest importance. A light weight acoustic device is probably the best approach to solution of the infantry company machine gun location problem at this time. Against mortars, a light weight radar is a distinct possibility. A device using thermal radiation from the hot weapon barrel might be a useful supplementary device and seems to warrant investigation.

2.23 At the present time night attacks are extremely difficult to undertake. The restricted observation ability and consequent lack of control after initiation of the attack seem to be the principal limiting features. Improvements to presently available infrared night viewing devices probably constitute the best immediate approach. Based on the assumption that an enemy will utilize techniques similar to our own, an enemy infrared capability would tend to neutralize any advantages obtained by our application. Accordingly, the alternative solution to the night attack problem is widespread battlefield illumination, after

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

2-5

which day tactics and techniques are employed.

2.24 The night defense situation of the infantry company presents a problem of detection and alarm against enemy surprise under the cover of darkness or from an unexpected quarter. Once a firefight is underway, night attack devices or techniques can be used. It is noted that heavier equipment can be tolerated closer to the front under stable defense conditions.

Three complimentary schemes are proposed for the immediate approach to the solution of the night defense problem, namely an acoustic-seismic detector, a radar personnel detector, and an infrared device. The acoustic-seismic device would employ microphones placed around the defensive position so that any enemy approach would be detected. Initially the microphones would be manually placed, and wire lines would be used to connect the microphones to the equipment at the observer's position. In addition, remote placement of the microphones using the rifle grenade or mortar wire laying technique would be accomplished; and later, radio replacement of the wire link would be the objective through development of an unattended, expendable transmitter for use at the microphone positions. A transistor device energized by radio waves or a purely passive technique seem attainable long time objectives. The radar personnel detector and infrared device would be patterned after the AN/PPS-1 and PSS-6. Improved MTI radar techniques would be sought as well as better IR devices.

2.25 The early introduction into the company of sensing devices justi-

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

2-6

fyng specialized separate data transmission or communications channels is not foreseen. Therefore the company system would transfer information by normal communications channels to other units. The early introduction of electronic navigational or position locating devices in the company also seems unlikely. It is likely, however, that the company elements might, on occasion, utilize a division or field army master navigation system when it is perfected.

2.3 A Regimental Combat Team System:

The RCT situation has several features from which its surveillance problems arise. Primary control of artillery is centered at this level, notwithstanding the quite common practice of occasionally concentrating control at division or corps level, nor the fact that medium and heavy artillery are normally controlled at higher than RCT level. Even in the latter cases target designation and fire requests frequently arise from RCT level. Adequate and effective use of artillery under ideal conditions requires observation beyond the capabilities of the unaided human. Artillery target detection, location, and finally friendly fire control are basic requirements. Another feature of the RCT situation is that movements are more likely to be preplanned on a day by day basis in contrast to the hour by hour informal planning requirement. It is then from RCT level that the requirements arise for reconnaissance patrols and aerial reconnaissance in depth. In addition the RCT is organized with transportation and with skilled technicians which give it the capability of handling heavier, more complex equipments than is

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

2-7

possible at lower levels. Thus the RCT might be the practical level for reconnaissance items to perform company or battalion functions but which items are too cumbersome to be normally used at those levels under the present state of the art.

2.31 Artillery in direct support of infantry is normally fired employing a front line observer accompanying the supported infantry. Through this medium, information acquired by the infantry company surveillance system can become the basis for artillery action. The location of enemy mortars for neutralization by friendly artillery fire is probably the most important single problem here. Radar at RCT level seems to offer the best chance of success; however, supplementary methods should also be pursued. Acoustic means give only limited hopes as the mortars produce little acoustic energy and are normally defiladed so that accurate sound ranging is not possible.

An airborne device is speculative for the mortar location mission, but warrants study. An equipment utilizing the mortar flash and employing a storage technique similar to the acoustic equipment AN/TND-1 is visualized; namely a TV scanning device sensitive to flash would feed information continuously to an indicator and to a storage device. Then a human interpreter seeing a likely flash on the indicator screen could immobilize the picture for determination of location. A variation presenting less technical difficulty, but having serious operational limitations, would be the use of the super-elevation advantage of a tower as a substitute for the aerial platform.

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

2-8

Counter battery fire presents similar problems to counter mortar fire and similar techniques are applicable. Here, since sound levels are higher, acoustic methods are well developed and utilized. The radar technique is under development. The speculative airborne flash technique discussed above as a counter mortar scheme would be applicable, as would an extension of the remote area acoustic sensing device discussed in paragraph 2.321.

2.32 Deep penetrating patrols serve several functions. No adequate electronic substitutes are offered to accomplish some of these, such as the capture of prisoners for interrogation, detailed route reconnaissance, or enemy strength probing. On the other hand several supplementary systems are proposed.

2.321 The remote located acoustic-seismic sensing device with radio reporting feature which was mentioned for the company system is also applicable here. Deep patrols, aerial drop, or artillery fire could plant the device at suitable locations to monitor communications routes. Under favorable wind conditions, it is possible to use this acoustic sensing-radio reporting device in expendable balloons tracked by friendly radar to provide position coordinates. Variations of this general technique might provide a limiting feature whereby the device would transmit only when the noise at the particular location exceeded a specified level; an interrogation feature whereby the device would transmit only when questioned by an airborne or ground transmitter; a storage feature which would allow accumulation of information for

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

2-9

subsequent playback; a directional sensing capability which would allow incorporation of these devices into a sound ranging system. All sounds transmitted back to RCT level from the various acoustic sensing devices could be subjected to analysis for source identification by the powerful LOFAR signature technique.

2.322 An RCT TV system is also visualized. Initial application would be in the form of a ground portable pickup camera transmitting its picture to a viewing screen over wire lines or a short range radio circuit. This type device would be used to monitor critical sectors of the terrain, to observe from exposed locations on the forward slopes of hills or on elevated towers, or to monitor choke points on enemy communications routes. In the latter application planting by deep patrol, helicopter, or air drop to overlook a bridge would be appropriate. Eventual solution of the vehicle, platform stabilization, remote control, and position locating problems should allow effective utilization of airborne TV as a replacement for the airborne observer at RCT level. This is a long term prognosis.

2.33 The proposed company employment of rapid photography is equally applicable to the RCT situation. Longer range cameras and other refined techniques could be used. In addition the proposed development of a remote controlled, stabilized vehicle operating in a position locating system would make available a platform for photography as well as for TV and other sensing devices.

2.34 A master position location system might eventually be developed

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

2-10

for application at RCT level. The objective would be to provide a system suitable for use as an artillery fire control grid. All elements of the command including observers and patrols would have devices allowing self-location in the grid. In addition, remotely controlled airborne vehicles would tie into the system.

2.341 As an approach to the master position location system, development of a radar, corner reflector, beacon technique is suggested. A radar sufficiently accurate in azimuth and range determination would be applied at RCT level to operate with corner reflectors and beacons supplied to friendly troops. Balloons or rockets carrying reflectors would be furnished to allow one-time "fixes" on the location of elements not in line-of-sight to the radar. Thus the radar position location system would provide a service to all elements by transmitting position data back to them over normal communications channels.

Such a system would be of considerable value in fast moving situations. It would have a technical advantage over some of the other navigational methods in that line-of-sight microwave frequencies are employed in concentrated beams, instead of omnidirectional medium frequencies which are subject to much greater distortion by local anomalies.

2.4 A Field Army System:

The field army surveillance problem is one of detection and location of enemy activity of such size and type as would require action at the field army level. The problem is better defined by consideration of examples. The field army is interested in enemy combat units of

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

2-11

about regimental strength or equivalent which are within striking distance of the field army. Specific enemy activity of particular importance are armored and motorized elements, which are capable of traveling up to 150 miles during the night; aircraft assembled on the ground at airfields within range of the field army weapons; missile launching equipment and operations; and all types of heavy structures, supply dumps, bridges, etc.

The field army has a general support mission to all its component units, and in the performance of this role it may utilize refined surveillance equipment and techniques not practical for use at lower levels. Such equipment may be placed at the disposal of lower units on occasion by the employment of teams detached from army level. Generally the equipment will probably be operated at army level and the information furnished to subordinate units as required.

The field army problem has a depth requirement far beyond the Regimental Combat Team and the Infantry Company. Two hundred miles has been arbitrarily chosen as the limiting depth for discussion by TEOTA. The army problem is also characterized by a wide variation in the time required for detection and in the case of large fixed installations, to times of order of minutes for aircraft assembled on the ground, and seconds in the case of an enemy missile launching operation.

2.41 Depth Requirement. The two hundred mile depth of penetration requirement of the field army has several general implications with regard to the accessories which must be used with the sensing devices.

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

2-12

Aside from radar none of the sensing devices under consideration have ranges anywhere near two hundred miles. Radar, while having that attainable range, is effectively confined to line-of-sight situations. For ground based radar over perfectly flat terrain, this characteristic would limit its use to targets higher than 35,000 feet above the ground. Thus the two hundred mile range imposes a requirement for a vehicle to carry the sensing device within range of the target. This, in turn, creates a difficult requirement for communication of data and for navigation or position finding.

2.411 In some applications of photography and radar, a vertically rising vehicle of the V-2 missile category would be suitable; but for most applications a horizontally traveling vehicle would be preferable. Initially it is believed that manned aircraft must be used to carry complex sensing devices to within range of ground targets. This belief is based in considerations of the fine control and guidance needed for many sensing techniques which can be attained only by humans; of the need for the return of the vehicle to bring back a record of observation; of the non-expendibility of many of the proposed equipments making safe return and landing mandatory; and of the possibility of effective evasion of enemy aircraft or anti-aircraft attack by a human pilot.

It is believed that the state of the art of guided missiles is such that an adequate vehicle can be developed for any of the long distance surveillance needs, but the design or selection of a particular missile will require a detailed knowledge of the sensing devices, the

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

2-13

communications requirement, the control method, and the navigational method. A detailed design was considered premature at this stage and none was made as part of Project TEOTA.

2.412 The field army surveillance devices will also require more complex communications facilities for those items which penetrate the two hundred miles. Both for control purposes and for continuous reporting of sensing device information, radio channels will be needed. Beyond ranges of the order of 25 miles a relay will probably be required for communications. Considerable developmental effort will be required to provide the equipment necessary for successful relaying because an intermediate relay station on an aerial platform is needed. This need arises from the fact that line-of-sight is elevated 35,000 feet above the ground at 200 miles and many sensing devices will probably be most effective at considerable lower altitudes. Pending development of a suitable communications system for the long range vehicle, programmed flight vehicles with radio control capability for part of the flight including landing would be substituted. Sensing schemes used in such vehicles would have to record or store information obtained at the extreme ranges for transmission at near ranges or for delivery upon landing.

Generally, while it is recognized that the two hundred mile penetration range will require a vehicle, a communications system, and a control or guidance system, it is not possible at this time to formulate preliminary designs or requirements for such items.

2.42 The Photographic System. Many of the field army level deep

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

2-14

penetration surveillance requirements can be met by photographic techniques. The principal operational limitation is weather, so that in some areas and in some seasons of the year, day by day photographic coverage is not attainable. However, fixed installations as large supply dumps, towns, bridges, railroad facilities do not change much day by day; so even the limited photographic coverage possible under bad weather conditions will produce useful pictures often enough to be of considerable value.

It is proposed to extend the photographic system of the field army by employment, first, of drones and, subsequently, of guided missiles carrying cameras in addition to other sensing devices. Photographic techniques would also be employed to record data from other sensing devices as, for example, radar mapping data.

2.43 Alarm and Detection System. One of the important surveillance requirements at field army level as at the other levels is warning of substantial changes in the enemy situation. Unusual or indicative motor movements, build-up for offensive action, armored reinforcements are typical changes of interest. Clues may be obtained from aerial photography, fragmentary information may be obtained from prisoners of war, deserters, or civilians; but there is a requirement for means to supplement and check other sources.

2.431 The proposed Regimental Combat Team acoustic-seismic beacon system should, when fully developed, provide valuable alarm and reconnaissance information in the zone up to about 10 miles in depth beyond the

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

2-15

front lines. It is planned to extend this range by the use of similar sensing means at field army level. The field army acoustic-seismic system would be based on aerial monitoring and interrogation of the remotely located sensing devices, as discussed in paragraph 2.321 above for the RCT, and the proposed information storage feature would be required to make the system feasible. The principal difference in the army level system as compared to the RCT level system would be in the use of drones or missiles capable of much deeper penetration either by actual travel or by line-of-sight communications to the remotely located sensing devices. Air-drop techniques, covert agents, deep patrols, all might be used to plant the beacons. Under favorable weather conditions, the balloon carried acoustic device could also be used at army level.

It appears that acoustic-seismic detectors utilizing the technical gain of extensive directional pickup arrays might be utilized to advantage. The detectors would be located behind friendly lines, but sensitive to noises arising deep in the enemy area. Such equipments would probably be applied at field army level because they would be too cumbersome and highly specialized to warrant use at lower levels. Serious evaluation of this method must await further detailed information on the magnitude of acoustic noises produced by military operations and formations.

A speculative technique which might provide an indication of unusual motor movements is gas analysis for combustion products. For example, a sensing device responding to the carbon monoxide content

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

2-16

might be flown over the enemy area at night to detect moving armored columns. The selective absorption of infrared rays by gases such as carbon monoxide would probably make feasible a simple device for this purpose. An alternative approach would be an ionization detector which might show the trail of a motor column by the variations in atmospheric ionization caused by the exhaust gases.

2.44 Target Location System. After some warning or suspicion of enemy activity is obtained by any means whatsoever, systems having greater resolution are necessary for location of the activity and identification of its nature so that action may be taken. Fire control of weapons represents the most refined aspect of the target location function. Systems having great resolving power are not operationally feasible for large area coverage because they produce too much raw data for review and interpretation. They also represent large logistic problems in application. For example, Project VISTA computed that 30,000 photographs would be required to detect and locate an enemy build-up in a 15 by 40 mile area for A-bombing purposes. A similar mass of data would result from application of high resolution radar. It will therefore probably be necessary to restrict use of the high resolution systems to areas of likely enemy activity as determined by the alarm type system and by other intelligence means.

It is visualized that high resolution systems will be made available at field army level for application as the situation warrants. The high resolution system will be built into vehicles which can be directed

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

2-17

to the suspected areas, and adequate communications and position finding schemes will be incorporated to provide location data.

2.441 For favorable weather conditions two techniques are proposed: photographic equipment similar to the deep area photographic system, paragraph 2.42, would be furnished with higher resolution and would be used at lower altitudes. In addition, drone or missile borne television system would be provided.

Initially existing television equipment would be adapted, probably with photographic recording in lieu of a 200 mile instantaneous data transmission capability. The low resolution of present television equipment would not satisfactorily meet the requirements so higher resolution would be sought and would be incorporated when available. Operationally, photographic recording, film recovery, and film processing would limit the utility of the immediate system, so a long distance data transmission capability would have to be provided for the ultimate system.

Illumination is required for effective night time use of both the photographic and the television systems. Instantaneous high intensity illuminants have been developed to a high degree of satisfaction for night aerial photography, and it is likely that these can be designed into the photographic drone or missile system. Suitable continuous illumination for night television, on the other hand, represents a problem the solution to which is not yet apparent. Study is required to determine the feasibility of attempting solution of the problem.

2.442 For bad weather conditions and darkness, primary reliance

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

2-16

would be placed on a high resolution airborne radar system which would have limitations similar to the proposed television system, excepting the bad weather or darkness limitation. The radar system would probably be more effective than television against camouflaged items, although skilled photo-interpreters are quite successful in overcoming the advantages of camouflage. For this radar system, as for the airborne television system, higher resolution would be developed than is currently available, and a data transmission capability is required. In fact, it would appear that interchangeable sensing devices, one for television, one for radar, might be used with identical vehicles, communications and position locating systems.

Supplementary systems which might attain a high degree of effectiveness against some types of targets are also visualized for use at field army level. It is believed that sensing elements for such systems might be made interchangeable with the proposed television and radar type elements utilizing the same basic vehicle, and the same ancillary systems for control, data transmission, etc. An infrared and microwave thermal radiation detector might be feasible with superior resolution against items of elevated temperature such as vehicles, aircraft on the ground, artillery pieces, etc. Similarly, magnetometer sensing devices might be superior against camouflaged massed military equipment.

2.443 It is believed that solution to the specific problem of surveillance and target location for the 280 mm. gun would be attained

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

2-19

by the combined development of the systems outlined above. The limited range of this weapon is about the same as the limiting range for line-of-sight radio communications without relay. Consequently the difficult development of the relay facility is not required for application of the sensing systems to surveillance for the 280 mm. gun.

Surveillance and target location for deep penetration atomic surface-to-surface missiles would be provided by a combination of the deep penetration systems discussed above.

A special meteorological problem exists in the tactical application of atomic weapons, namely the determination of weather conditions over the target to insure that proper use is made of the weapon and that no injury to friendly troops results, without resulting injury to friendly troops. This problem can probably be solved by the application of drop radiosonde techniques developed for normal weather observation over enemy or inaccessible areas.

2.444 A very difficult problem will exist at field army level in the surveillance for enemy long range missile activity. Launchers for long range surface-to-surface missile are visualized as simple mobile equipments not readily distinguishable from heavy construction equipment by sensing devices at a distance. Such launchers may remain in firing position only for a few hours. Some information on enemy missile activity will be furnished through interpretation of data from the surveillance system already discussed, but a satisfactory system based on detection of launchers or stored missiles is not foreseen.

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

2-20

A related problem is the detection and location of enemy surface-to-surface missiles in flight for destruction by friendly surface-to-air missiles before arrival at their destination. Approach to the solution of this problem appears to lie in the simultaneous extension of mortar or artillery shell radar techniques, the stabilized aerial platform, and the radio relay communications system to provide an airborne missile locating radar which will feed coordinate data into computers controlling the friendly firings.

2.45 Proposed Prototype Systems. In order to provide for early evaluation and a means for continuous experimentation of sensing means, it is proposed to commence immediately the planning and assembly of a prototype Army system. It is proposed to equip a heavy aircraft, such as a Constellation, with a high power, high resolution, side-looking radar which would use advanced MTI techniques for the function of area surveillance. Long range cameras, acoustic beacon interrogators, and radio relay equipment would be added as feasible. Operationally, the aircraft would fly at altitudes so as to probe continuously behind the enemy lines. Friendly fighter aircraft would be provided for protection as required. Intelligence would be displayed in the aircraft or preferably relayed to ground control stations.

Upon detection of suspicious activity by the surveillance aircraft, more refined techniques would be placed into operation by the ground control stations. With the present state of development,

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

2-21

liaison or high performance aircraft with human observers and photographic equipment would be utilized. The ground stations would control these planes using radar and voice frequency radio to direct them to the suspicious areas and to receive reports. Subsequently short range radar, infra-red detectors, magnetometers, etc. would be incorporated into these aircraft. As the feasibility of drone and missile reconnaissance was demonstrated, they would be substituted in this role for the manned aircraft. The heavy aircraft should be available as an airborne platform to carry relays for control and communications circuits for the secondary research vehicles. It is planned that the secondary search vehicles would be controlled from the ground independent from the primary area search aircraft which would go on performing its continuous patrol.

It is recognized that considerable operational testing and evaluation would be required to settle both the technical details and the operational use of this system. It is believed that such evaluation must proceed in pace with systems planning and equipment design.

2.46 Operational Analysis. It should be re-emphasized that effective results will be accomplished only by development based on systems planning rather than on opinion, speculation and unrelated end-item equipment development. It is doubtful that any of the above discussed systems will prove practical in precisely the form presented. However, the most promising items must be selected and field trials

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

2-22

held under conditions such that parameters can be measured and operational analysis used to evaluate the effectiveness of equipments and methods of operation. Then continuous system development and analysis ensues producing the most useful results for the expenditure of time and money. It is therefore recommended that Project TEOTA set up a systems evaluation group at an early date to aid in planning and testing. The Operations Research Office, Johns Hopkins University, the Combat Development Agency of Army Field Forces and the technical resources of Project TEOTA might combine to make an effective team to solve the battlefield surveillance problems.

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

CHAPTER 3

Photography

3.1 Introduction

The inherent capabilities of photography have resulted in its widespread application to problems of the battlefield, and today it is probably used as much as any physical technique in the collection of intelligence. In addition to being a means of surveillance in itself, photography also can be utilized with other sensing devices because many other types of surveillance information are enhanced when associated with good photographs of the area under study. Photography offers a promising future because its many capabilities have not been fully utilized as applied to the surveillance problem and because of the many technical advances which are being made in the field.

A photographic surveillance system may be considered as being comprised of several links each with separate functions. The photographic equipments and techniques may be discussed conveniently as they pertain to these functional links. The links are:

A. The gathering of intelligence, including consideration of cameras, films, vehicles for carrying cameras, and illuminants for night photography.

B. The conversion of intelligence into interpretable form, which is concerned with development processes and printing techniques.

C. The transmission of data to photo-interpreters, including devices for procedures for accomplishing distribution.

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

3-2

D. Photo-interpretation, including consideration of the process of extraction of significant information from the mass of raw data contained in a typical photograph.

The general nature of photography, its present capabilities, and its limitations by conditions of low visibility are quite well known so that a detailed exposition is considered unnecessary. However, it is of interest to consider a photographic film as an electronic instrument, since within each grain, latent image formation is an electronic process. Absorbed light liberates electrons which migrate to sensitivity specks. Silver ions are collected at these specks and amplification amounting to a factor of many million occurs when the film is developed. Thus the film as a whole may be regarded as an aggregate of hundreds of millions of detector-amplifier combinations which are arranged in parallel. A single print may contain tens of millions of elementary bits of information. By way of comparison, the standard television picture presents only about 200,000 bits of information per frame, or about 2 per cent of the information which a good print may show. Even a poor print may contain many times the information presented on a TV screen.

In addition to its very high resolving power, a photograph has the advantage of being a permanent record, easily studied, copied and filed. Pairs of photographs permit stereo viewing giving three dimensional effect. Photographs taken one day and compared with those taken

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

3-3

previously permit the detection of changes, such as night time construction of fortifications and attack preparation.

Project TEOTA has noted references to weaknesses in the photographic surveillance system as presently available to ground troops which it is believed result from inadequacies in organization and procedures rather than from limitations of photographic equipments and techniques. No comprehensive study has been made by TEOTA of these aspects of the photographic surveillance situation. Likewise no study has been made of the last function listed above, that is, the process of photo-interpretation by which essential information is extracted from the photograph. It is believed that operations research systems-type evaluation studies are required in this area.

3.2 Cameras:

Cameras of many types have been adapted to or developed for military use; and generally speaking, the performance characteristics of these equipments are well known, so that Project TEOTA did not attempt to catalog them. The military needs for ruggedness in construction, simplicity in operation and satisfactory mechanical operation under wide ranges of temperature and humidity, pose requirements which are difficult to meet, so improvements along these lines are always desirable. In addition it is desirable that the intelligence be gathered in usable form for rapid evaluation. Thus cameras incorporating "rapid photography" techniques in which the gathering and conversion steps are combined are of great interest. These techniques will be discussed in par. 3.5 "Processing".

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

3-4

Models of a 10" Spotting Camera, weighing 6 pounds, utilizing the Land-Polaroid process, are currently available for military evaluation. The test models are limited to moderate temperatures and to slow repetitive rates. It is expected that tests of this camera or its modifications will indicate whether the Land-Polaroid process as presently available is adequate for military use.

For more refined work, development has been initiated on a 40" Reconnaissance Camera (PH-631()/PF) capable of utilizing either the Land-Polaroid or conventional film. It is intended that this camera be vehicular mounted for use under all conditions of climate and terrain. It is believed that targets such as machine gun emplacements will be detectable at ranges of 2000 yards on photographs from this camera.

At longer ranges, the use of a longer focal length lens camera from fixed ground locations is possible. Thus a 100" camera (AN/PFH-2()) at an elevation of 250 feet can detect such detail as bridges, roads and railroad tracks at 20 miles. Of course clear line-of-sight optical paths are necessary for effective use at such ranges, which greatly restricts ground utilization of such cameras. When natural elevation is lacking, such a camera might be used atop a 200 ft. tower or with small captive balloons. Here, as is the case in many other photographic applications, extensive field testing and operational analysis will be necessary to determine the real military value of equipments and techniques which are already available.

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

3-5

When penetration of the forward airspace is possible, the conventional cameras, either hand-held or in simple mounts, can be used in the army liaison aircraft for obtaining large scale, low oblique pictures. The Spotting Camera (10" lens), the 70 mm. Combat Camera with an 8" lens and rapid cycling, or the K-20 modified to use 12" lens may be used. For vertical photographs the liaison aircraft may mount the K-24, K-25 or K-44 (12" lens).

Under combat conditions which preclude the use of liaison aircraft over enemy areas, such planes flying behind friendly lines at altitudes to be safe from enemy long range ground fire can be used. In this case larger cameras are required to produce usable photographs, and technical problems arise in anti-vibration and motion compensating mountings. An L-20 aircraft at 15,000 feet bearing a 100" camera would produce a photograph on which a 20 foot object is recognizable at 25 miles (scale 1:15,000).

It is believed that camera techniques are now available to develop suitable items for application to drones and missiles as required. Prototypes which might be used as bases for such development are the Army 70 mm Combat Camera, the Air Force P-2, and the Navy CAX-12. In such an application, the recovery of the camera or the photograph would present a considerable problem. It is possible that further study of this particular problem will indicate the superiority of alternative methods such as using unreturnable vehicles with facsimile or television transmission to return the visual intelligence.

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

3-6

3.3 Vehicles:

Men, trucks, towers, liaison aircraft, balloons, and helicopters have been mentioned as suitable camera carrying vehicles. Frequently the camera would be in addition to the normal equipment and function of the vehicle; but in some cases, as the tower or the 100" camera in the L-20 aircraft, a special camera vehicle would result. However, the camera and mount could be installed or removed from the airplane in a short time so the plane need not be exclusively used for photographic work.

While not designed to be load carriers, the characteristics of anti-aircraft target drones indicate possibilities as photographic vehicles. For example, the Q-2 drone, which will fly 35 minutes at 500 miles per hour and 1000 feet altitude, could be fitted with a 70 mm. camera having motion compensation and an anti-vibration mounting. In this application a 3" lens would provide a 1:4000 scale photograph of an area 125 miles long and 750 feet wide on a 200 foot roll of film. It should be noted that this particular assemblage has not been developed, but no great difficulty is foreseen in its development. However, many technical problems would have to be solved in order to provide a prototype for test.

Specific guided missiles, which are already developed, such as the Matador, Corporal, and Hermes offer possibilities as photographic reconnaissance vehicles in the near future because of their altitude capabilities for long range photography. High altitude photographs

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

3-7

exposed during the unpowered portions of flight should yield acceptable definition. For example, at an altitude of 50,000 feet, a usable photograph (scale 1:65,000) should be obtained of a target 100 miles distant with a 100" focal length camera.

Free balloons because of their altitude capabilities might serve as vehicles for long range reconnaissance. Excellent photographs have been made from such balloons at an altitude of 95,000 feet. The problem of recovery presents a major obstacle to the use of both the high speed, high altitude missile and the free balloon. In addition the free balloon presents problems in guidance and navigation.

3.4 Illuminants:

The inadequacy of photography in darkness is a very serious limitation and a night photographic capability is one of the most urgent photographic requirements for Army units. Night photography requires auxiliary illumination as films are not sensitive enough to react under the very low quantity of night illumination. A photographic material of great sensitivity would eliminate this need for auxiliary light sources; but, while steady improvement has been made, it appears unlikely that film sensitivity can be improved sufficiently in the near future to eliminate the auxiliary illumination requirement. In any case, the use of artificial illumination would produce better photographic results even if the sensitivity were increased several-fold over that which can be presently foreseen.

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

3-8

At the present time, a passable picture can be obtained with Kodak Tri-X Aero film with approximately four foot candles of illumination. Infra-red film of high sensitivity is also available which allows the use of infra-red filtered light source where surreptitious photography is wanted.

Auxiliary sources of illumination which have been used in practice are pyrotechnics, either in the form of illuminating shells or photoflash bombs. In both cases, adaptation to army needs is technically feasible; however, the use of auxiliary illumination sources greatly increases the complexity of the photographic system. For example, for shells, coordination procedures are required between the weapons, which are usually remotely located, and the camera. For aerial missions photoflash bombs are of such bulk and weight that few can be carried, and in some applications a separate aircraft is required to transport the illuminants in addition to the camera plane. Such complexity tends to make the systems unworkable.

For illuminating shells, an 81 mm. mortar would give a range of about 2500 yards, a 155 mm. Howitzer a range of about 18,000 yards. Airborne photoflash bombs of various sizes are available. The L-19 liaison aircraft can mount two photoflash bombs as the T-115 or M-120, while the L-20 can carry four larger type bombs as the T-92.

Sources of illumination other than pyrotechnics should be investigated in an effort to avoid the limitations of pyrotechnics. One type which might be exploited for military night usage is the electrical

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

3-9

flash method developed for high-speed technical photography. Some work has apparently already been done in this respect, but details were not uncovered by Project TEOTA. Development has been started by the Army Signal Corps of an infra-red flasher source which would permit surveillance of an area about 800 yards in diameter at a range of about 2000 yards.

No difficulty is foreseen in the adaptation of illuminants to remote controlled drones and missiles in the event future development should result in their use for camera vehicles.

3.5 Processing:

Much of the reconnaissance for the smaller tactical units is concerned with "targets of opportunity", and time is of utmost importance so that military action may be taken. Accordingly all steps in the photographic process should be accomplished very quickly. Some recently developed techniques of "rapid photography" show considerable promise, and these should be further improved and evaluated for military use. In addition conventional processing methods have been speeded considerably, particularly in the use of machines for the processing of large quantities of film and prints.

3.51 Land-Polaroid Process: The best means known to be available currently for rapid photography is the Land-Polaroid process, which is capable of providing a positive transparency or reflection print within 40 seconds after exposure. The process in practice at the present time does not produce archival prints, nor duplicates; although means have

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

3-10

been developed for producing copies rapidly and simply. The materials best suited for this purpose are available only in limited quantity, but there is no inherent limitation to the quantity production of such materials should the demand for them be developed.

Certain apparent disadvantages of the Polaroid process as currently available have been noted, such as the short time deterioration of the prints, the temperature limitation, low resolution compared to that attainable with conventional methods, and questions as to the perishability of materials which might require special handling in the military supply system. It has not been clearly demonstrated that the advantages of the Polaroid process outweigh its present disadvantages and limitations as applied to the military photographic needs. Evaluation of this process in the photographic system wherever possible is urged, as is the encouragement of further development to overcome its limitations or to develop other rapid methods.

3.52 Electrostatic Photography: (Xerography) There has been developed a technique of electrostatic photography which, like the Land-Polaroid Process combines the first and second links of the photographic system to produce a single positive transparency in about 50 seconds. This technique shows promise of development of duplicate prints; and the devices are capable of being operated in the presence of radiation fields which might nullify film type processes.

3.53 Kodak Development Film: The Kodak Laboratories have under development a material which is processed by a new reversal technique

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

3-11

which depends on the fogging action of special emulsions by certain types of developing agents. A single developing process produces a positive rather than a negative, and either negative or positive reflection prints may be obtained by the process. The important characteristic of this new material compared with previous autopositive materials is that it has a speed equivalent to the slower speed negative films and, therefore, the total processing time may be as short as three minutes. Processing equipment for limited quantities can be simple and compact.

3.54 Kodak Processing System: The conventional negative-positive processing technique is still the most practicable for applications requiring large quantities of photographic work, as Area reconnaissance coverage. The Kodak Research Laboratories have produced a system which will produce one print of excellent quality from each negative of a 9½" by 200 foot roll of aero film in about 30 minutes. The first print is available in about 15 minutes; and additional rolls of exposed negatives may be spliced onto the one in process.

This processing system uses two new photographic materials and three new machines. The materials are a pre-hardened SuperXX aero film which can be processed at 85-95°F and a multicontrast paper for which the contrast is controlled by variation of the color of the printing light. A negative processing machine processes the pre-hardened film in about 3 minutes, including drying. The contact printer automatically measures the minimum and maximum densities of

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

3-12

each negative to be printed and then prints the negative onto the paper at the correct exposure and contrast. A paper processing machine processes the paper in about 17 seconds. While washing can be accomplished by these machines, suitable materials exist for non-washing procedures on these machines. These equipments are heavy and require considerable electric power, as about 30 kw. is required for them of which 19 kw. is used solely for the rapid drying of the film after development.

3.55 Mobile Processing Laboratory: Mobile laboratory darkrooms are available for use wherever a 2½ ton truck can operate. These are completely self-contained with their own water and power supplies. They contain all facilities for processing film from 35 mm. to 9½ inches wide and are operable under all climatic conditions.

3.56 Multiple Prints: The Kodak Research Laboratories have developed a lithographic material with which half-tone images may be made from either negative or positive photographic originals, allowing production of lithographic prints within 5 minutes. Such a device would permit reconnaissance photographs, which could be annotated if necessary, to be produced in adequate quantities for military needs.

3.6 Transmission:

The delivery of the photographic information from the processing place to the photo-interpreter is the third link in the photographic system. A number of instances have been cited which indicate weaknesses in the functioning of this link in the field. This is considered

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

3-13

to be a defect in organization and management which could be corrected by operational analysis. On the other hand, certain technical means are available to assist in the delivery of the finished print to the interpreter. Of course the elementary scheme is to use mechanical delivery from the laboratory to the interpreter, and in this scheme man afoot, vehicle, aircraft, and even carrier pigeons may be used. In these cases the speed of transmission and delays are primarily those attributable to the messenger.

In addition to the mechanical means, two electronic systems are available for the delivery of prints, namely television and facsimile. The transmission in either may be wire or radio. Television transmission is limited by the resolving power inherent in the presently available television systems. Considerations of improvements in television systems are given in the chapter on Photoelectric Devices. On the other hand facsimile systems, which can sacrifice speed for quality, do offer pictures of excellent quality, so degradation of the picture cannot be attributed to the facsimile transmission system limitations.

3.7 Interpretation:

Photo-interpretation has been done by highly trained persons with little assistance from machines and devices. Project TACIT and others have considered some aspects of this operation including the use of stereo cameras and flicker presentation as aids to interpretation. As shown by the example given in para. 2.44 and in the introduction to

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

3-14

this chapter, photographs contain literally millions of bits of information. Much of this information is extraneous and must be discarded by filtering out the few meaningful bits. Alternative reconnaissance techniques which directly detect and present a higher degree of pertinent information without the extraneous information appear to be in the future. Accordingly every effort must be made to speed up the interpretation of such currently available systems as the photographic. An operational analysis type study of the photo-interpretation process might be valuable, and development of devices to assist the photo-interpretation step should be indorsed.

3.8 Conclusions:

The major effort in development of military photographic systems and techniques has been expended in improving large format photographs from photo-reconnaissance planes and further improvements along this line can be expected. However, while such photographs are of great value for strategic purposes, the inherent delay between the time of request and the availability of pictures to front line commanders render them of less value in tactical operations. It is also apparent that photography has not found its place in tactical reconnaissance for diverse reasons despite its availability for many years. Therefore, a major effort should be directed towards making photographic reconnaissance benefits readily available to tactical units. This effort should include both the field evaluation with analytical studies of the effectiveness of photographic reconnaissance in units of division size

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

3-15

and smaller and the research and development of photographic techniques and equipments to meet the needs of those units.

For night time photography, supplemental illumination will probably be required for many years to come, and although pyrotechnics have been developed extensively for this purpose, other possibilities exist and should be explored.

3.9 Recommendations:

a. A comprehensive program of field evaluation and operational analysis is recommended on various phases of the application of photography to military reconnaissance, including:

1. Extensive trials of the 10" Spotting Camera, Cameras with longer focal lengths, cameras suitable for mounting in Army liaison aircraft, and the Land-Polaroid technique.
2. Study of the procedures and organizational factors in the current method of performing tactical photographic reconnaissance.
3. Indorsement of the Project TACIT proposals with respect to stereo cameras and the use of towers or captive balloons for elevated photographic platforms.
4. Study of the photo-interpretation operation, and devices to assist in this operation.
5. Studies of possible military applications for the Kodak heavy duty processing equipments, for the multilith reproduction technique, and for such other techniques as result from the research and development efforts of the photographic industry.

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

3-16

6. Research and development of techniques and equipment in the field of "rapid photography" is recommended, including:

1. Improvement to the Land-Polaroid process.
2. Exploitation of the Xerographic technique (Electrostatic Photography).
3. Sponsorship of additional techniques which show promise of providing finished pictures faster.
4. Indorsement of development of faster films, faster printing and processing methods for conventional type photography.

b. Investigation of illumination sources for night photography as alternatives to pyrotechnics.

c. A systems analysis study be made of the proposed drone or missile photographic systems as compared with the Haller, Raymond and Brown line scanning technique and television techniques. Assemblage of items for a drone or missile photographic system should be deferred pending accomplishment of this systems study.

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

CHAPTER 4

RADAR

4.1 Introduction:

Even though radar has been in fairly widespread use for nearly 15 years, it still possesses capabilities for surveillance beyond those which have been exploited to date. This does not mean that progress has been lacking in all phases of radar applications to specific battlefield problems, but rather that the full capabilities of radar, and its place in any overall comprehensive system of battlefield surveillance has not been critically assessed.

As a sensing means, radar may be considered to supplement a variety of other sensing techniques, all of which are under examination in this TECTA report. Under some circumstances radar is preferable to other means of intelligence gathering. The reasons for this, in an approximate order of importance, are:

- a. The ability of radar to penetrate darkness, fog, and foul weather for relatively great distances.
- b. Its ability to detect moving objects by means of the doppler effect.
- c. Accurate range and high range resolution are directly and linearly obtainable.
- d. Radar camouflage is considerably more difficult than is optical camouflage.
- e. Certain weather data, such as cloud base and top indication, can best be gathered by means of radar.

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

4-2

As with other methods of surveillance the primary tasks are detection, location, and identification. Most of the radar work to date has been concerned with detection and location, that is, with getting from a localized position in space, defined by the range and the antenna's angular position, a signal return larger than background noise. The existence of a target in that volume is often enough to insure its military interest, as in early warning, or changes in the exact location may be of prime interest as in tracking. In many of the reconnaissance tasks for which radar may serve, but particularly for airborne reconnaissance, there is adequate radar power to enable us to "detect" targets of military interest at reasonable ranges, and in combination with navigation techniques to be discussed elsewhere in this report, "location" of the target element in map coordinates can be obtained. The most difficult task and the key to the radar problem in reconnaissance, is "identification". Identification or interpretation is taken to mean full determination of the nature of a target -- whether a rock, a tree, a fence or a building, supply dump, vehicle or tank, or other item of military importance.

The ability of radar to look through darkness, fog and foul weather will not be useful unless the channel of information consisting of return reflections can be decoded or interpreted. Each elementary volume of space, hereafter called a radar element and defined roughly as determined by one angular beam width and one pulse length of the radar used, may return a signal pulse. In ground surveillance there is no

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

4-3

inherent military significance to whether or not that spot is "occupied" or gives a return signal. It may be a tree instead of troops, a rock instead of a tank, a mountain instead of a city. To determine whether or not a radar element is of military significance, multiple data elements must be obtained and all possible correlations must be sought, as, for example, correlations between successive range elements, between successive sweeps, between successive scans, between successive days.

Human intelligence must be brought to bear in separating items of military interest from background. In photographic reconnaissance, much time and effort have gone into interpretation. Use is made of all possible optical parameters--fine detail, shades of gray over a wide dynamic range, color, stereoscopic vision, comparison with silhouettes or photographs of our own and enemy implements of war, and much experience on appearance of terrain features. It seems that to date no integrated attack has been made on exploration of all the methods applicable to radar for improving the identification of radar returns, although some aspects of the problem have been attacked to a greater or lesser extent.

4.2 Radar Techniques:

This discussion of techniques will be categorized according to methods of improving identification. Techniques pertinent only to extending range, reducing size and weight, increasing locational accuracy, etc. will not receive the same emphasis, since the military and industry

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

4-4

have already recognized their importance. Improvement of the identification of a radar signal element might be achieved in many ways and combinations of ways. All involve multiple data elements obtained from that particular object and comparison of the pattern or correlations within this set of data with model patterns of objects of interest obtained by calculation or past experience. All the possible parameters of the radar signal must be considered as potential sources of data.

Some of the sources for identification data are:

1. Detail structure -- The relative amplitudes from adjacent range and azimuth elements, which with adequate resolution, would clearly depict the shape of the object.
2. Variation of the radar return with time -- On the one extreme, by comparison between successive sweeps, detection of moving targets (which as a class are of military interest) is possible. On the other extreme, comparison of the radar return from an area over long periods of time -- days or months -- may indicate changes, such as construction, destruction, or assemblage of military items.
3. Gradations in amplitude of the radar signal -- whether a large or small object is involved.
4. Multiple channels -- otherwise called monopulse offers additional data for identification.
5. Polarization characteristics -- the relations between incident and reflected polarization.
6. Variations in response with transmitted frequency -- in some ways analogous to use of color photography.

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

4-5

7. Variation with aspect angle -- when radar reconnaissance looks at a target from several directions, items cancelled or minimized in one direction may appear in others.

In this report more space is spent on the discussion of items 1 and 2 above, not because these are the only ones of importance, but because the effects here are immediate and known, and in our opinion the state of the art in these directions is ready for a considerable advance leading to hardware in a reasonable time. It is our recommendation, however, that analysis and experiment be undertaken, geared to supplying creative effort and critical evaluation to all the above means of identification. This should be followed by data gathering, and developmental work on the methods that appear promising. Such a study could be very rewarding.

4.21 Detail Structure: Some information concerning the size and shape of an object will result if the amplitude from the radar element under survey, and the relative amplitudes from adjacent range and azimuth elements can be compared. Moreover, the use of high resolution techniques, which reduces the size of the radar elements, adds to the precision of the information concerning the object. High resolution techniques may assume several different forms, and operate on different principles. However, the objective in all cases is to secure as much shape detail as possible.

A direct approach to high resolution is afforded by the reduction in the size of a given radar element. To accomplish an increase in

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

4-6

range resolution necessitates a reduction in the pulse width. Present methods are available which make pulses having a time duration of .01 microseconds feasible. Pulses of this time duration permit resolution in range of the order of 5 feet, which is deemed adequate for most surveillance operations. While a limit to the extent of reduction of a pulse is imposed by the frequency of the primary radiation, this is not of particular consequence with the frequencies normally used for radar devices. Moreover, with the higher frequencies contemplated for future developments, this becomes even less of a restriction.

A direct reduction in the beam width is accomplished by two methods, namely, a reduction in the wavelength of the radiation; an increase in the aperture of the antenna. The question of the wavelength for radar operations is influenced by many factors, included among which are: the effective scattering cross-section of the target as a function of frequency, the range requirements, whether MTI techniques are necessary to the operation. An analysis of the problem of airborne radar for long-range mapping applications has been undertaken by the Beacon Hill group, with the following recommendations: that the K_u band be treated as the basic wavelength for long range mappings; that the K_a band be developed for future use where extreme range is not a requirement; that the 0.35 cm wavelength offers sufficient promise for relatively short ranges to justify vigorous research and development. These recommendations are sensibly extended to include certain ground-based radar surveillance requirements, although it now appears

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

4-7

that the recommended 0.35 cm might better be taken as 0.43 cm. Some work is now in progress at SCEL which seeks to develop the 0.43 cm wavelength region.

The question of wide aperture antennas must be discussed in terms of beamwidths desired, and wavelength used, since the term is a relative one. An approximate relation among the parameters is the following

$$\text{Beam width (deg)} = k \frac{22.52 \text{ (cm)}}{\text{Aperture dimension (inches)}}$$

The quantity k appearing in this relation takes account of the character of illumination of the reflector, and varies from unity, for the case of uniform illumination across the aperture, to a value perhaps as high as 2 for a tapered illumination such as might be considered usable for certain applications. The permissible side-lobe level might influence the character of the illumination used, and hence the value of k. Note that a 0.5 deg beam at 1.86 cm required an antenna with an aperture of at least 7 feet. While such antennas are quite feasible for ground use, the problems are somewhat more difficult for airborne use.

For normal type scanning radars which incorporate PPI type displays, the size of the aircraft imposes severe restrictions on the physical dimensions of a scanning type antenna that is possible. Equipments of the APS-20 and APS-23 types make use of 8 foot and five foot antennas respectively, but larger antennas are difficult. With a side-looking radar, scanning may be accomplished by the motion of the aircraft. Also, since a non-scanning linear array is used to produce a

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

fixed fan beam which is perpendicular to the center-line of the aircraft, this linear array being mounted lengthwise along the aircraft, the length of the array is not subject to the same limitations as the scanning array. Thus antennas which are in the 10 to 20 foot length range are quite possible, thereby making very narrow side-looking radar beams available.

The scanning speed of the side-looking radar is relatively low. As a result, the prf of the radar can be materially reduced, and still maintain a sufficient density of radar echoes to insure scanning without scanning loss. This permits the use of relatively low duty cycle equipment, with its consequent smaller size and lighter weight. In addition, such side-looking radar has possibilities for the inclusion of doppler techniques for increased resolution, as will be later discussed. For these, and other reasons to be discussed, the use of side-looking radar holds tremendous promise as the high resolution reconnaissance and mapping radar of the immediate future.

The side-looking radar incorporates a non-scanning linear array antenna which is mounted lengthwise along the aircraft. This may either be mounted in a narrow nose nacelle projecting in front of the aircraft, or it may be mounted in nacelles attached to the fuselage lengthwise along the aircraft. The antenna provides a fixed vertical fan beam approximately at right angles to the aircraft's course. Two such antennas placed back to back will provide beams on either side of the aircraft, so that a wide swath of the terrain is scanned by the forward motion

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

4-9

of the aircraft. The radar information is recorded on a slowly moving strip chart, range information being recorded as a transverse trace on this strip. The resulting strip chart is an approximately true Cartesian coordinate map of the scanned terrain.

The techniques of strip mapping are not yet in a completely satisfactory state. Initial work on the APQ-38 strip mapping radar utilized a facsimile recorder with only one range being sampled at a time. Since the information from all other ranges at this time was thrown away and few hits per target resulted, it was felt that range was sacrificed. Integration in a storage tube to retain all the information and read it out at a rate within the capabilities of the facsimile device has been resorted to. The Beacon Hill Report suggests the use of a continuous-strip photograph of the face of the cathode ray tube on which is painted the single electron beam trace. The advantage of the photographic link is the wide dynamic range that is available, which will permit the recording of the full radar information without manual gain adjustment.

A method of ground mapping by Doppler analysis has been suggested by Dr. C. W. Sherwin of the Control Systems Laboratory at the University of Illinois. This method provides a means for obtaining a radar map of very high angular resolution using relatively broad beam antennas. In this scheme, a broad microwave beam is directed at a fixed angle of roughly 30 deg with respect to the aircraft's heading. A narrow range gate selects returns at a discrete range. It is found that an appre-

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

4-10

ciable difference exists in the Doppler frequency beat with a coherent reference signal between two points on the ground that differ only slightly in azimuth. Frequency analysis of the echoes from the two points permits them to be observed separately. Thus a series of audio filters is used in effect, to divide the arc of the illuminated ground within the range gate into many small angular increments. As the plane moves, the arc is swept along the ground, making possible a strip map which should resemble the strip map generated by the side-looking radar. An angular resolution of $1/10$ deg appears readily attainable. The implementation of this doppler technique imposes a range limitation since with the high pulse repetition rates needed, ranges of the order of several miles would be the present possibility. However, since there is considerable need for relatively short-range high resolution surveillance equipment, this method possesses considerable promise in this application.

A new method of ground mapping by Doppler analysis has been suggested by Mr. Walter Hausz of the General Electric Co., Electronics Laboratory. This method is not subject to some of the limitations of the Sherwin approach, as it does not suffer the range limitation, it does not require the high prf, nor is there any need for the bank of tuned filters and the commutative scanning of these. He proposes that a side-looking radar (with a beam width as narrow as consistent with frequency and antenna size) look in a direction normal to the aircraft's flight. Within this beamwidth, targets have different radial

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

4-11

components of velocity caused by the aircraft's motion. Hence the Doppler beat with a coherent reference signal will vary from several hundred cycles per second at the beam edges to zero on the antenna axis. By presentation means that integrate or effectively filter out all but the zero beat a considerable improvement in resolution can be made. A more complete description will be found in TEOTA Memorandum No. 20.

4.22 Variations with Time: Moving Target Techniques. Changes with time in the radar return from a given volume of space may result either from movement of objects within the volume or from changes in the dimensions or aspects of the objects themselves. Since the dynamic features of a battlefield are generally of particular military significance, the direct detection of objects whose positions or dimensions have changed, to the exclusion of other objects, is a technique of exceptional value. Basically, these changes in radar return are detected simply by comparing observations made at different times, but the time scale of the observations may be very different for different purposes. For direct detection of objects in continuous motion, the change in phase of the return from moving objects may be observed continuously or sampled at a pulse repetition rate, giving rise in either case to a Doppler frequency. For detection of objects in discontinuous as well as continuous motion, the change in position can be observed by comparing observations made at intervals of seconds, minutes, or even days. This technique, usually known as "area-storage MTI", is

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

4-12

obviously applicable to the detection of changes in dimensions or aspects of stationary objects, such as might characterize the build-up of troop and vehicle concentrations or of a supply dump.

To a greater extent, perhaps, than in other radar applications, the processing and presentation of data constitutes a problem in MTI systems. Accordingly, in the following pages, after a general discussion and a few illustrations of the various types of Doppler systems, considerable attention is given to the various types of data processing schemes (and components thereof) in use or proposed for use with pulse-Doppler systems.

Both c-w Doppler and pulse Doppler systems are in use today for detection of moving targets. In c-w systems the transmitter output itself is used as the phase reference, while in pulse systems, a phase reference is provided either internally by a signal coherent with the transmitter signal, or externally by the return from ground clutter and stationary objects adjacent to the moving object. The former technique is known as "coherent" MTI and the latter, "non-coherent" MTI.

In its simplest form, a c-w Doppler system consists merely of a c-w transmitter, a receiver, and an indication means. Echo signals are combined in the receiver with a sample of the transmitter signal, and the resulting doppler components are detected aurally. The relatively long integration time required by the ear affords a high degree of discrimination between pure tones and noise. In order to provide range information, it is necessary to incorporate frequency modulation

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

and ranging circuitry. These simple c-w techniques have been employed in the Signal Corps AN/PPS-1 personnel detector, and modifications necessary to permit ranging in this equipment are currently under development.

In coherent pulse Doppler systems, several techniques are available for establishing the local coherent phase reference. One of the simplest schemes conceptually, employs an echo box. This scheme is being exploited in Project Lincoln and, while bulky, appears to be satisfactory for short range operation. In another scheme, also being studied in Project Lincoln, a parallel arrangement of IF delay lines of different delays serves to accomplish the same functions. Though somewhat more complex, conventional techniques involving the use of coherent oscillators have received considerable attention in recent years, and both ground based and ship borne equipments of this nature have been constructed. These systems are regarded as undesirably bulky and difficult to maintain in their present stage of development.

Application of coherent MTI techniques to airborne use is troublesome because of the difficulty of compensating precisely for the radial component of aircraft velocity at all azimuth and depression angles. However, Dr. C. W. Sherwin of the Control Systems Laboratory at the University of Illinois has recently pointed out that such compensation may not be necessary and that by carrying out a spectral analysis of the complex return, moving targets may be identified.

In non-coherent MTI systems, the ground clutter serves as a phase

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

4-14

reference. Thus the Doppler frequencies in the return are those due to motion of an object with respect to the ground. This technique is therefore well suited to airborne ground surveillance for ranges in which clutter is predominant. The AN/APS-26A radar equipment represents an application of this technique.

The useful sector of scan in such systems is limited, however, by the fact that Doppler components arise in the clutter return itself as a result of different radial velocity components of objects within the illuminated area. Thus it is estimated that for an airplane velocity of 500 miles per hour and a 7.5 degree beamwidth, the useful sector of scan extends to approximately 13 degrees from the ground track.

This limitation on the sector of scan can be partially avoided by effectively eliminating the aircraft motion between two successive pulses. In a Philco development this compensation is achieved by using two antennas mechanically displaced along the ground track by an amount depending upon scan angle and aircraft speed. By employing two antennas and suitably arranging the parameters, the target is effectively viewed twice from the same position in space. The same objective is achieved electronically in a GE proposal for a mono-pulse system in which the relative gains of two receiving channels are varied to shift the effective antenna center. Both schemes are necessarily limited to a pulse-to-pulse subtraction type of data processing such as described below.

Pulse doppler techniques are being studied after application to

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

4-15

light weight hand-carried equipments for personnel detection. The Signal Corps Engineering laboratory is currently modifying a light-weight beacon into a non-coherent personnel detection equipment. Coherent techniques also offer possibilities for this application. Proximity fuse techniques may also be profitably applied for application to personnel detection and these possibilities might well be explored.

There are a number of techniques for processing the data derived from pulse doppler MTI systems. One of the simplest forms, sometimes referred to as Butterfly, provides means for processing only a single range sector from each sweep. The essential elements, (which may be incorporated in a conventional radar system) consist of range gating circuitry, a pulse stretching type detector, and aural detection means such as earphones. Processing is accomplished by sampling the radar video with a narrow range gate and storing the information in a capacitor, which retains the data until the next sample occurs. Thus the output level changes in accordance with the pulse amplitude variations. Since the amplitude of each sample is the resultant of the phase addition of clutter and signal, a target moving with respect to clutter will produce a variation in pulse amplitude from sample to sample, thereby providing an audio component which indicates target motion.

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

4-16

A rather different technique for deriving and processing MTI data on a selectable range sector basis has been suggested by Dr. R. M. Page of the Naval Research Laboratory. In this system, which is a coherent pulse Doppler scheme, both transmitter and received signals are heterodyned to video frequency signals by a local oscillator operating at approximately the transmitter frequency. The converted transmitter signal is made available for use as a coherent reference by storage in a lumped-constant video delay line with multiple taps. Detection is accomplished in a bank of bridge multipliers each of which is supplied with the coherent reference signal from a delay line tap. The delay line thus operates as a range gating system and from the output of each multiplier a signal containing information derived from a known element of range is available. The output of each detector or any combination of them may be manually switched to the input of a low-pass integrating amplifier for aural presentation. The system is described in some detail in TEOA Memo. No. 1.

A fundamental limitation of both this technique and the Butterfly scheme is imposed by the use of a single processing channel. When aural detection is employed, about 1/2 second is required to recognize a tone, and therefore each element of area in the field of view must be examined for at least this length of time and therefore scanning speed is low. By the same token, of course, sensitivity is high.

The limitation on scanning speed can obviously be relieved by providing a multiplicity of storage elements and processing channels.

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

4-17

In the simplest example of this (a multiple Butterfly arrangement), separate capacitors are each fed by a different range-gated video signal. Enough adjacent range gates are used to provide coverage of the range of interest. Associated with each storage element is a bank of tuned reeds which performs the integration and presentation functions. This approach is being pursued in Project Lincoln.

A more sophisticated form of multi-element storage is accomplished by delay lines. In these devices video information may be stored in range sequence without accessory switching. In application of delay lines to MTI storage, video signals from one sweep are subtracted from the delayed signals of the preceding sweep and the differences are displayed in PPI fashion. Because of the sequential nature of their output, delay lines are not readily adaptable to integration techniques. Examples of the use of delay lines are found in the Firefly (APS-27) equipments, which are non-coherent MTI systems.

An interesting concept by means of which rapid data processing can be achieved, involves storage of MTI video data in a multi-element storage organ in which the read-out sequence may be made independent of the input sequence. This concept is exploited to some extent in the Doppler B-scan and more thoroughly in a development known as Sinufly. In the Doppler B-scan (applicable to either coherent or non-coherent MTI data), a series of range scans are displayed in raster fashion on a long persistence cathode ray tube. Video data is impressed by intensity modulation. Since corresponding range elements lie alongside

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

4-18

one another, a fixed target appears as a solid line at right angles to the range scan, while a moving target appears as a series of bright dots due to the audio component of the intensity modulation. Some indication of relative velocity can be derived from the dot spacing. In this scheme, integration is obviously visual.

The Sinufly system, under development at the Control Systems Laboratory of the University of Illinois, uses a storage tube such as the RCA Radechon for multi-element storage. MTI data is stored in the tube in the same rectangular coordinates as in the Doppler B-scan and is then read out at right angles. In this manner corresponding range segments from a number of scans are rapidly examined. Since the read-out can be very fast, a time scale compression is effected, thus converting Doppler components to a higher frequency where tuned filters can serve as practical integrators. The integrator outputs in turn serve to trigger indicating pulses on PPI display which is synchronized with the storage tube readout. This system makes effective use of integration, hence, its sensitivity is greater than that of Firefly.

Most MTI techniques, either coherent or non-coherent, are seriously limited by the multi-element storage organ. Currently the best developed devices for this application are acoustic delay lines. Both the mercury and the quartz lines, however, have some severe limitations. Their inflexible delay requires that the radar prf be precise. While substantial improvements have been made in the design of quartz lines

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

4-19

in recent years, both the mercury and quartz types have high attenuation and require extreme linearities in the associated circuitry. The delay is limited and since the output from a delay line subtraction system consists of the difference between successive scans, low velocity sensitivity is limited.

Storage tubes are receiving only moderate emphasis for MTI application, yet there are a number of advantages to be gained if they can be utilized practically. The radar prf is not critical. Readout sequence can be independent of input sequence, thus facilitating the use of integration techniques. Time-scale compression is possible on readout, thereby conveniently providing Doppler frequency conversion. Practical utilization of storage tubes in MTI requires concentrated efforts both on tube development and on circuit techniques required for their application.

As already discussed, the detection of very slow motion or long term variations in radar return is best accomplished by Area Storage MTI, since Area Storage MTI provides a means of comparison over a flexible time scale. Radar data from one complete azimuth scan is stored for subsequent comparison with data on a later scan. The interval between successive comparisons may be from scan to scan, from minute to minute, or even longer depending upon the expected rate of target motion. Buildup of troop and vehicle concentrations or supply dumps, for example, might best be detected by comparison of scans taken on an hourly or even on a daily basis.

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

4-20

Because of the large number of elements per azimuth scan and the long storage time required, there is a serious problem in providing a suitable storage system. At the present, conventional photographic mediums, though cumbersome to process, appear best adapted for this application. The use of cathode ray storage tubes has been explored by RCA on a Signal Corps contract. With further refinement, xerography or other mediums of multi-element storage may become feasible for this application.

In connection with the display of Area Storage MTI, and possible for applications which combine Doppler MTI with normal PPI presentation, considerable enhancement may be afforded by the use of stereo or multi-color presentations.

4.23 Gradations in Amplitude: Dynamic range in a radar system has not been pursued adequately to date. The conditions of radar viewing and the limitations of the display device have made it difficult for the viewer to appreciate more than two or three tones between black and saturation and often he has substantially a black and white presentation - no gray scale at all. It is obvious that in photographic interpretation such gross distortion of the contrast scale would greatly hinder identification of targets. It is not clear that quantitative presentation of the amplitude of radar return would in itself identify any target, but in combination with other methods it is probable that valuable deductions can be made. Small targets can be distinguished from large, small variations in amplitude on successive

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

sweeps or scans can be noted, detail present in an area of solid clutter can be seen. A very wide dynamic range must be handled, amounting in some cases to 120db, but usually proper radar design will reduce this, and logarithmic compression may be used to give approximately constant percentage sensitivity.

With several outstanding exceptions, wide dynamic range is attainable in most parts of the radar system. The weakest link is the display system. The radiating and receiving system by use of antenna pattern shaping and sensitivity time control can remove much of the variation in amplitude due to factors other than target size. In tracking systems AGC can be used to maintain accuracy over wide dynamic ranges. Problems in dynamic range exist in MTI although frequency or phase modulation have shown promise of alleviating them.

In the display, conventional cathode ray tubes with long persistent phosphors and wide variations in brilliance within a few angular degrees, due to the scanning method have obscured much of the amplitude information beyond simple detection. In the field of television so much has been done to improve dynamic range that immediate exploitation for radar is possible and desirable. Aluminized cathode ray tubes with adequate voltage and attenuating face plate materials give considerably more independence from ambient lighting conditions, from halation, and from saturation due to blooming. Some work has been done with this type tube for radar, but it is not yet assured that future radars will take advantage of these developments. The use of transparent

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

4-22

phosphors should be explored as a technique which may permit a further increase in the available contrast range. Means of display other than CR tubes, with possibly inherently wider dynamic range have been proposed. The ultrasonic cell and the electro-optic effects possible in such crystals as ADP are two methods of light modulation suggested.

The limitations on discernible amplitude steps imposed by scanning rates and the finite decay time of phosphors can be reduced by displays that repeat the radar picture at a rate over the flicker threshold. In some cases, such as BuAer's "Nighthawk" being done at RCA, antennas with very rapid scan rates are under development. Antennas capable of scanning up to 1440 RPM have been built for the Navy APS-8. Other experimental projects have been exploring the use of slower scan rates, storage of the radar information and multiple read-out at some 30 times per second to permit a bright display well above the flicker rate.

The above methods seek more discernible shades of gray between background and peak illumination, to represent the intensity of radar signal return. Several more indirect methods have been proposed. One method, explored by WADC, uses non-linear techniques to display amplitude information; three or more intensity levels are derived from final amplifiers that saturate at widely separated dynamic range levels. Another, also explored by WADC, proposes to use color to represent dynamic range on the basis that the eye will respond more readily to this under normal display conditions. For example low amplitudes, such as background noise, might be presented in blue. When the blue amplifier

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

4-23

saturates, another amplifier covering considerable dynamic range portrays its output in green. An amplifier whose output is portrayed in red, is cut off for all except very strong signals. This may be very effective, but of course the equipment is quite complex. It should be noted that color in the display can be used as another dimension to display any one, two, or three identifying characteristics, so it is probably not economical to use it to display target amplitude only.

4.24 Multiple Channels: The simultaneous reception of information on several channels, whose responses are differing functions of the angle between the target and the antenna axis has been called monopulse. Basically, combination of the simultaneous data can give accurate angular information. By extension it might be applied to the simultaneous reception of data functionally related to characteristics other than antenna pattern, for example, the simultaneous reception of return signals of two polarizations, discussed in Section 2-6 below. As a means of giving angular data within the beam width it has proved useful in tracking, or accurate continuous location of a target, and was explored for this purpose by M.I.T., N.R.L. and G.E.Co. during the last years of WW-II, and since then by many contractors. Successful tracking radars using it have been built (NIKE by BTL, and APQ-42 by GE as examples).

The possibility of using the extra information obtained by the multiplicity of channels for improved display or identification has received some attention. Since the exact angular location of a single

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

4-24

target in a radar element can be determined on a single pulse there is no need to have on a PPI display an arc one or more beam widths wide representing that target. In G.E.'s proposed system called MRI (Monopulse Resolution Improvement), which has been flight tested in breadboard form, a signal representing the angular error information is used to move the cathode ray spot to the correct target position by deflection as necessary at right angles to the sweep direction. In the Maxson Company's APQ-45 (a PPI display which has been flight tested) and APQ-38 (a strip mapping system), the angular error signal is used to blank out the cathode ray spot except when the error signal is zero within specified limits. Both systems improve the display on single targets as much as would several fold increase in antenna size, but on a complex target within a beam width, the advantage is not as great, nor the interpretation as easy as that obtained by antenna size increase.

The "Beacon Hill" report has recommended the direct approach of frequency and antenna size increase as most fruitful in improved resolution and target identification. We concur that the direct approach is more certain and, at the present state of the art, ripe for more rapid improvement. We wish to note that many of these other techniques, including monopulse, are not incompatible with high frequencies and large antenna sizes. When the limits of a particular vehicle and set of weather conditions have been reached by size and frequency increase, monopulse can still be added if more resolution is needed, is

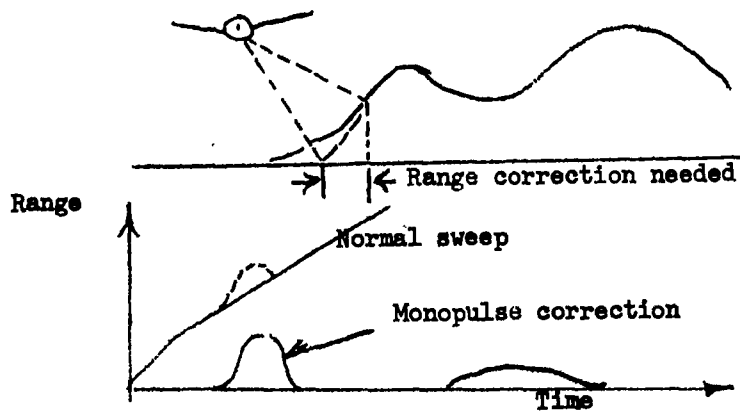
SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

4-25

justified by the display, and is worth the cost.

Angular information within the target, obtained by monopulse, can have other advantages in identification and location besides "beam-sharpening". Statistical variations in the angular information from pulse to pulse as the antenna is rotated indicates target complexity and a single target can be distinguished from a complex one. Angular information in elevation may be added to a mapping or surveillance radar to permit identification of targets by elevation - that is to separate out such targets as helicopters, planes, barrage balloons, etc. In mapping in other than smooth terrain, positional errors occur on the display, even if it is corrected to give ground range instead of slant range on a flat earth, because substantial deviations from flatness occur. A first approximation to correction of this may be made by using monopulse height information as a deflection along the sweep as illustrated in figure -



SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

4.25 Polarization Characteristics: If every radar target were a perfect sphere and there was only one per elementary volume, the radar return would always have the same type of polarization as the transmitted signal (but reversed in sense for circular polarization). Since targets are more complex than this, their effective area is not the same for all types of polarization, and in fact each type of incident polarization can give reflections containing all possible types of polarization. To define completely the effective target area would require a matrix which includes all the possibilities of polarization conversion. Actually there are only six independent parameters, and one such set consists of the return from CW circular polarization as measured by received CW and CCW circular polarization and the phase angle between them, and the return from CCW circular polarization which is similarly received as CW and CCW polarization and the phase angle between them. All the variants of linear and elliptical polarization can be derived from this set.

Some attempts have been made to seek superiority of one polarization combination over another for specific purposes. For rejection of rain clutter it has been reported (by A.I.L. and others) that transmitting and receiving in circular polarization of the same sense will reject rain clutter by over 20db at a loss of only 6-8db on desired targets over what is obtained by linear polarization. Claims of superiority of one type of linear polarization over another for specific target classes do not appear well proven. The amplitude of return for various

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

4-27

polarizations from various types of target, from mortar shells to tanks and planes have been measured as a function of aspect angle by the Ohio State Experimental Station. But to the best of our knowledge no one has tried to study completely correlations among the six parameters associated with the polarization on reflection from a target. Due to the pronounced variation with aspect angle, such measurements would be a tremendous multidimensional task, but there is evidence that the statistical approach can give useful information.

Mr. G. E. Hart of NRL has performed interesting experiments in which he transmitted circular polarization of one sense and received simultaneously both senses of circular polarization. Thus it might be called a monopulse system with two simultaneous data channels. Since single reflections, as from planar or spherical objects returns one polarization, while double reflections as from a right angle between two rocks or buildings, or between a tank and ground, return the other polarization, one expects each radar element to return a combination of these polarizations depending on its nature. He presented on an A scope either the two returns sequentially with opposite polarization, or the difference between them as a bi-polar signal. As might be expected, sea clutter and land clutter were statistically divided about equally between the two polarizations. Also, it fluctuated rapidly between the two, particularly where motion was involved (sea clutter or land viewed from a plane). The difference signal then showed both polarities and would average zero over any appreciable period of time.

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

4-28

Large discrete objects, however, while they could be of either polarity, tended to remain of the same polarity. When the large object was moving, such as a plane, it fluctuated in polarity but at a slower rate than the clutter. Thus differences in correlation of power spectrum were observed that could be used to identify or separate large discrete objects from area clutter. This might be of great usefulness if MTI is reduced in effectiveness by tactics of pulling off the road and stopping when a plane approaches.

Integration other than visual (that is, storage tubes or delay lines) could increase suppression of rapidly fluctuating components to increase the advantage. Other combination signals formed from the two polarizations and the phase angle between them could be displayed, perhaps by using color in the cathode ray tube as the display dimension. Successive pulses could be transmitted on opposite senses of circular polarization so within two pulses all six characteristics of the target could be explored. It appears that further experimental and theoretical evaluation seems justified.

4.26 Variations with Aspect Angle: It must be apparent that a side looking radar, seeing terrain from only one aspect angle, will miss some targets which are obscured by terrain features. Of course, on successive days of flights the battlefield can be divided into strips in different manners, so over a period of time each elemental volume is viewed from a large number of directions. The alternative system, which might be considered to be another mission, comprises the vehicle

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

4-29

that takes a look at a suspect area from a number of different aspects over a short period of time, perhaps then to be repeated. This might be to get additional identity data, to penetrate camouflage and obstructing terrain, as well as to watch changes over a short period of time, such as for shell burst spotting. The type of radar required would presumably be closer to the conventional mapping radars such as the APS-23 than to a strip mapping radar.

In addition to covering areas otherwise obstructed, change of aspect can give considerable identity data since the multiplicity of target elements located in a radar element, which combine vectorially to give the radar return, will total differently for different viewing aspects. In toto these responses of a radar element as a function of aspect constitute the "radiation pattern" of that elemental volume. The Ford Instrument Co., a Sperry Corp. subsidiary, have written an extensive report on radar-photo interpretation, developing the feasibility of drawing conclusions as to the nature of a target from such a set of responses. For example, a building with large flat surfaces would show peak returns with direction that would be absent from a circular gas tank. Stereoscopic viewing of two frames corresponding to radar maps made several minutes apart might also be considered as a variation of aspect for improved identification.

4.27 Variation with Frequency: The last of the parameters of a radar system which may be manipulated to aid identification is the r-f frequency. This, in the broadest sense, would include not only the

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

4-30

determination of what frequency band to use for optimum identification of one class of targets, but also would include the use of multiple frequencies or a band of frequencies to obtain more information about the target.

In only a few cases has the frequency of a radar been determined by the reflectivity characteristics of the target. One such is the cloud base and top measuring radar, the AN/APQ-39, which is on Ku band because high frequencies are necessary to get appreciable reflections from the clouds. Even here a still higher frequency than that currently used may be more desirable, but this is presently limited by current state of the art. A second case where the character of the target has materially influenced the choice of radar frequency is in aircraft search, although in this application several frequency bands are used, depending on whether the function is early warning, height-finding, or fire-control. In the case of surface search radar, the normal sea clutter has had an influence on the choice of frequency. For the general class of targets with which we are here concerned, it does not appear that sufficient measurements have been performed to permit a definitive recommendation. Attention is called, however, to the tentative recommendations contained in Sec. 4.21, as to preferred wavelengths.

According to current information theory, the information possible over a channel is proportional to the bandwidth of the channel. Moreover, it is possible to relate the well known principle that the shorter

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

4-31

the pulse length, and so the greater the range resolution, to bandwidth considerations, since the bandwidth is inversely proportional to pulse length. Thus, by halving the pulse length or doubling the range resolution, twice as many discrete data elements, or twice as much information is received. An r-f pulse of .01 microseconds, which is about as far as the state of the art has gone, contains the carrier frequency and sidebands extending 100 MC on each side of the carrier. Only for a target located at a specific range will all sidebands be in phase at a particular instant in time delayed from the transmitted pulse.

Beyond a certain point, shortening the pulse length becomes undesirable because enough average power in the pulse cannot be obtained to get adequate range. One way around this, which has been explored at Britain's S.E.R.L. and in this country at BTL, and discussed in the Beacon Hill report by S. E. Miller, is the proposal to use f-m within a pulse. In this scheme, the r-f frequency is varied by say 100 MC within say a 1 us. pulse, and then, on reception, a network in the r-f or i-f channel delays differently the sub-elements of the pulse (by using the fact that they differ in frequency) so that at the output all sub-elements are simultaneous. The performance should be equivalent in every way to the transmission originally of a .01 us. pulse of the same average power (or 100 times greater peak power).

There are, of course, limits in the present state of the art on the bandwidth that can be included in a single pulse. Several means

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

4-32

of getting some information on the response characteristics of a radar element over a wider range of frequency ranges have been suggested. At WADC, experiments with "polychromatic" radar have been made in which simultaneous transmissions at S and X band were made and combined on the PPI. The principle purpose was "fill-in", i.e. to avoid, by statistical means, the blanking of a radar element because all sub-targets within it happen to cancel. The extension of this work that is planned calls for simultaneous transmission at two or more frequencies in the X band, thus avoiding the lower resolution of the S band.

It is suggested, since ECM projects under way are seeking to make it possible to transmit successive pulses on considerably different frequencies within the same band, that utilization of a series of frequencies on successive pulses within the beamwidth corresponding to one radar element can give identity information that might be called a "signature spectrum" characteristic of the target. This term is broader than the "color" of a target and comes closer to the chemical identification of elements or compounds by emission or absorption spectra. Many problems of technique and display exist and will be raised as objections. A possible implementation is described briefly primarily to suggest that the technique merits further evaluation.

Consider a radar, either an airborne mapping radar with PPI, or a ground based surveillance radar. Let it normally operate on one frequency, say in the X band. Let the previously discussed means of identification be used to the maximum extent. It can have a short

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

4-33

pulse of say .02 us. and a beam width of say 0.6° . There can be MTI to distinguish fixed targets from moving targets. Now suppose that a non-moving target is discovered that is regarded with suspicion - perhaps a tank or vehicle that is stationary and under light optical camouflage. A photo-electric probe is focussed on that particular spot of the PPI and the radar system is switched to vary frequency from one pulse to the next. With a .02 us. pulse the sidebands in one pulse are 100 MC in extent, and successive pulses need not be closer than 50 to 100 MC apart. At 1000 pulses per second and ten scans per second there will be 16 pulses per beamwidth so sixteen frequencies, 50 MC apart, or covering 800 MC at X band could be used. The output of the photo-electric probe is a series of pulse amplitudes that can be displayed either directly as amplitude, as time, or pulse number, or can be fed to a filter bank to separate the pulse-to-pulse variations into its characteristic frequency variations. A total bandwidth of 800 MC would permit examination of correlations within the radar element corresponding to separations in space of one foot or less. For example, a target area composed of two sub-targets separated by three or four feet would show several whole cycles of sine wave variation of the photo-electric probe output of the frequency corresponding to that separation. Many target types may have strong periodicities, such as the cleats on a tank which are regularly spaced. These might provide information from which an experienced operator could draw detailed deductions on identity.

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

4-34

Searchlighting on a particular target would, of course, permit more hits for identification, which would be used to cover a wider frequency band - say several thousand megacycles at Ka band, thus giving correlations down to inches. If the system is airborne in a pilotless vehicle, either the probe must be directed by remote control to a particular target area, or some less general means of transmissible display, such as tri-color tubes, must be used.

4.28 Passive Microwave Detection: Considerable interest has been shown in the potential use of the passive detection of thermal radiation at microwave frequencies as a mapping method. The possibilities of this technique have been discussed for a number of years, but it is only with the improvement that has already been made in the development of broad-band amplifiers, and the possible future improvements, that the technique appears to be feasible. Some basic considerations underlying thermal radiation and the important aspects of its detection are contained in the Beacon Hill Report. The significant considerations are also contained in TEOTA Memo.No. 2.

In view of its potential value, it is important that whatever work is done in this field be carefully watched and encouraged, so that the developments proceed in a manner to insure its ultimate applicability for military use.

4.3 Radar Devices and Programs

The principal techniques that furnish some contribution to the radar problem of identification of targets have been discussed in

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

4-35

Section 4.2. It is the purpose of the present section to discuss some of the newer equipments which are in preliminary stages of development, or which are nearing the production phase, as they bear on the military problems. In several cases, detailed recommendations are included of systems which appear to have potential value and which have not been fully exploited. In these cases, what is proposed might not be an ultimate solution, but it might be of value in stimulating progress.

4.31 Personnel Detection: The problem of detecting personnel in the battlefield is one of detecting targets of fairly small scattering cross-section (of the order of one square foot) in the presence of much larger signals from the ground and from any enveloping undergrowth.

A stationary man exhibits no known radar characteristics which are particularly different from the radar characteristics of the surrounding terrain, and it is virtually impossible to distinguish him from the terrain return. It appears conceivable that man or his equipment might possess different resonant frequency patterns or different polarization patterns from those of natural terrain patterns. These might be utilized to advantage in the detection of stationary personnel. A comprehensive program for the measurement of the echoing area of a man for different frequencies and for different polarizations of the incident radiation is recommended.

For the detecting of moving personnel, the Doppler effect is used

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

4-36

effectively in both c-w and pulse types of radar equipment. Several equipments are in process of production and development.

4.311 The AN/PPS-1 is a c-w doppler system that operates at a frequency of 10,000 mc; total weight about 30 pounds. Detection range on a man walking at 3 mph over unobstructed terrain is about 500 yards. Trucks moving at 15 mph can be detected at 2000 yards. The equipment is mounted on a tripod, and uses an 18-inch parabolic antenna. The microwave source is a klystron, with a radiated power of about 5 milliwatts. The presentation is aural, the operator detects the doppler frequency by the use of a pair of earphones. The equipment provides no range information.

The Signal Corps has a contract for 50 personnel detectors, type AN/PSS-6. This set combines two distinctly separate operations; one being the AN/PPS-1 c-w doppler radar; the other being a combined infrared search light with a viewer in the near infrared. The range of the infrared system on personnel is 200 to 300 yards. The weight of the combined equipment is to be about 100 pounds. Delivery is expected to begin in February 1953, and to be completed by July 1953.

A more advanced form of the c-w doppler radar AN/PPS-1(XE-) is under development at SCEL. The new design will incorporate a one watt c-w magnetron in place of the klystron. Also, an f-m system for ranging will be incorporated into the equipment. A detection range of about 2000 yards on moving personnel is expected to result from the increased power. It is estimated that models of the improved design will

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

be available for field tests in about one year.

4.312 Butterfly type equipment is still in the experimental and testing stages, with considerable interest being shown by the Signal Corps, Marine Corps, and by Project Lincoln. The Marine Corps has been testing a truck-mounted experimental equipment, frequently referred to as "Truckfly." This experimental set comprises a modified AN/APS-19 radar, which has been equipped for aural detection of moving targets. By moving both the antenna and the range gate in a suitable program, a circular zone of 120 deg width and 1/2 mile depth is scanned in 30 to 40 seconds. Provision for mechanically sector scanning the antenna over narrow limits after detecting a target to provide fairly precise bearing information is incorporated. Detection ranges of 2000 yards on personnel are possible, with ranges of 15 miles on moving vehicles in unobstructed view having been reported. The experimental equipment weighs about 500 pounds, less power unit, but it is anticipated that equipment designed especially for Truckfly use would be in the 300 pound or lighter class. According to the latest reports, the Marine Corps is planning to place an order for 20 units which closely resemble the experimental Truckfly equipment. Delivery could probably be effected during 1953.

A Butterfly kit has been developed for the AN/MPQ-10 equipment, with provision for the aural monitoring of a gated range sector. Two laboratory developed and manufactured kits, by SCEL, were taken to Korea by NEI teams in December 1952 for field trials and operational

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

4-38

evaluation.

4.313 The rough details of a cross-correlation type of system have been discussed by Dr. R. M. Page of the Naval Research Laboratory which, in principle, possesses the elements of a light weight operable system for personnel in the presence of some undergrowth. Details of the proposed system will be found in Appendix B.

4.32 Mortar Location: Mortars are ordinarily concealed from direct observation from opposing lines. Consequently, ground based systems for mortar location must depend on the detection of projectiles in flight. By determining the position of the shell in flight, the trajectory may be extrapolated backwards to its point of origin. Since mortar shells provide small targets, a figure of $.03 \text{ ft}^2$ normally being taken as a realistic value of average scattering cross-section, detecting equipment is necessarily high power, with attendant large size and considerable weight. No approaches for the development of small, light weight equipment are presently in view, although in the light of its importance, considerable effort in seeking and exploring new avenues in this connection is deemed most desirable.

Mortar locators under development are of three types, one type being a scan and track system, the other two being non-scan systems. In the scan and track system, the system in its first phase is continuously scanning a specified sector. When a target is detected, the antenna is positioned and tracking is started, although it is often necessary to wait for a second round from the same source before

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

tracking can be accomplished. The seriousness of this delay is the subject of some disagreement, and an operations analysis of the question might be an effective way of resolving the disagreement.

4.321 The AN/MPQ-10 is currently the established standard mortar location radar for the Army. It is a tracking radar operating at a frequency of about 3000 mc, with a peak power output of 200 kw. The antenna is a 69 inch paraboloid, with an antenna beamwidth of 5 deg. In its scanning operation, a sector, adjustable from 200 to 800 mils, is automatically scanned in three seconds. When a target appears on the B-scope display, the operator manually positions the antenna and a range marker to the location of the target. When the next shell appears, the system is thrown into automatic tracking, and the shell is tracked. Range, azimuth, and elevation data are plotted on the RD-54 plotter during tracking. From these plots, the trajectory is extrapolated to its origin by using templates. The reliable range of the system on mortar shells is about 7000 yards, with ranges to 10,000 yards possible under favorable conditions. Field tests have shown that the accuracy requirement of 50 yards in the location of mortars is satisfactorily met.

The radar equipment together with its companion equipment, the RD-54 plotter, is permanently mounted on an M-2 gun carriage. The entire system, including carriage, weighs about 7200 pounds, less the primary power unit. Orders have been placed with the Sperry Co.

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

Production of 25 systems per month is expected to begin in March 1953.

4.322 The AN/MPQ-7 is an experimental S-band equipment which operates in much the same fashion as the AN/MPQ-10. It is considerably lighter than the AN/MPQ-10, and is to weigh about 3000 pounds, including radar, built-in computer, and trailer. The design provides for a lower silhouette than the AN/MPQ-10. Field trials will probably be held early in 1953. If these trials are successful, limited production may be undertaken during 1953. An X-band r-f system is being designed, which will be interchangeable with the S-band system.

4.323 The AN/MPQ-4 is an experimental non-tracking system which operates at 1.86 cm. It is provided with a dual antenna system, one antenna being mounted above the other. A beam, which is 0.8 deg in elevation and 1 deg in azimuth is scanned through a 25 deg sector, first at one elevation, then at a second elevation, two degrees higher than the first. A shell in the field of view of the antenna is observed at two elevations, and two points on the rising portion of the trajectory are displayed on a scope. An operator positions two markers on the two spots. The position information of the markers is fed to a computer which, by linear extrapolation, determines the approximate origin of the trajectory. The maximum range of location is expected to be in excess of 7000 yards, depending on the size and aspect of the shell being observed.

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

4-4i

Present plans indicate that a development-production type of contract may soon be negotiated. This will provide a completely mobile system, built into a trailer, and weighing about 3000 pounds, less power unit. Initial delivery of production equipments might be expected during 1955.

4.324 The AN/KPQ-1 is an experimental non-tracking system, which is being developed by the Naval Electronics Laboratory for the Marine Corps. In its current state, it consists of 6 parabolic antennas arranged 3 wide and 2 high, the r-f being switched successively from one antenna to the next at a 6000 per second rate. It is expected that the antenna system will ultimately consist of 3 double feed pill-boxes stacked side by side. A shell in the field is observed on four antennas, two to give azimuth information, and two to give elevation information. The echoes from the four dishes are fed into a computer for the determination of the track and the point of origin. This information is to be fed directly from the computer to the counter-battery groups. Owing to its present preliminary form, production stemming from this development would not be available before 1955.

4.33 Machine Gun and Small Arms: To locate machine guns and small arms would require a radar having operating characteristics not unlike that required for mortar location. It has been estimated that for a radar system of moderately high resolution to detect small high-velocity projectiles, such as .50 caliber machine gun bullets, sub-clutter

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

4-42

visibility of the order of 70 db would be required. No method now exists by which radar techniques can contribute to the machine gun location problem. Effectively the problem of locating machine guns, if done at all by radar, seems to be one of detecting moving personnel.

4.34 Artillery Location: An artillery location radar, like the mortar location equipment, must locate batteries which are concealed from direct observation. It must determine the location of the battery by extrapolating the trajectory of the high velocity relatively low angle projectile to its origin.

4.341 The AN/TPQ-5 (XE-1) artillery locator and counter-battery fire director is a tracking radar system of advanced design, under development by the General Electric Company. Operation of this equipment is generally similar to that of some of the mortar locators discussed in Section 4.3. A narrow beam scans an azimuth sector, but conversion to tracking operation is automatic upon the detection of a signal. For favorable situations, only one shell is required for location.

The system operates at X-band, and radiates a peak power of 1 megawatt. A six foot antenna produces a beam 1.2 deg wide which is scanned through a 20 deg sector at a rate of 5 scans per second by means of a Foster scanner. A set of feeds for tracking is mounted directly above the Foster scanner, and the dish is so designed that, with a change in polarization introduced in switching feeds, the tracking beam coincides in elevation with the scanning beam. A microwave switch, which operates in 0.1 second, switches the feeds at the initiation of the tracking

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

4-43

phase. Directional information is derived in a combination phase and amplitude comparison monopulse system. A tracking accuracy of 0.1 mil is sought. Provision is made for two or three pulse coherent MLI, to be available at the discretion of the operator, for discriminating against stationary targets and low velocity targets. Detection range of the system is 15,000 yards, and impact locations to 24,000 yards are expected. The expected error in location is less than 50 yards. An increased range to 50,000 yards for tracking one's own shells, an anticipated use for atomic artillery, will be included in the system. This development will lead to a system which weighs approximately 10,000 pounds. The first models are expected in 1955.

4.342 The AN/MPQ-21 (XE-1) is an interim equipment which is to satisfy an immediate need for a radar tracking device for the 280 mm atomic war-head shell. It will consist of a modified SCR-584 having a ten-foot antenna, and the addition of a modified RD-54 plotting board. This combination will permit tracking of shells out to 20,000 yards or more. As many as ten or fifteen of these equipments may be provided to meet immediate demands during 1953.

4.343 As a longer range program aimed at solving the 280 mm shell tracking problem, a development-production type contract is now in the process of negotiation to obtain a small number of AN/MPQ-21 (), a modification of the AN/MPQ-10 set. This modified equipment will have a power output of one megawatt, provision for beacon coding, an 8 or a 10 foot reflector. Delivery of the first of approximately forty units

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

4-44

is expected during the latter half of 1954. Since delivery of these sets is expected before the AN/TPQ-5, there is some possibility that it might be employed for artillery location, as well as for its 280 mm shell tracking role, on an interim basis.

4.35 Moving Vehicle Detection: The detection of moving vehicles presents roughly the same class of problem as the detection of moving personnel. Owing to its generally larger silhouette, and the fact that the vehicle may be moving at greater speeds, the problem is less difficult than that of detecting moving personnel. For the detection of moving vehicles, the Doppler effect is used effectively in both c-w and pulsed types of radar equipment. Very high resolution pulsed radar systems also possess some possibilities for this application.

There appears to be no portable equipment in process which is designed specifically for the detection of moving vehicles. However, the AN/PPS-1 and the AN/PSS-6 discussed in Section 4.31 would be quite suitable for this purpose. The Truckfly development described in Section 4.321 is also particularly applicable.

4.36 Weather: Conventional radar techniques have been found very useful for the accurate positioning of meteorological phenomena and of presenting weather information. Such data is of considerable importance in facilitating a higher degree of accuracy in weather forecasting. Both ground based and airborne equipments are being developed for this purpose. The Ka band ground based TPQ-6 and the Ku band airborne APQ-39 are for cloud base and top indication. The APQ-40 is an x-band

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

4-45

airborne weather detection radar, the CPS-9 is a ground based storm detector. It appears that the existing developments will adequately satisfy the weather needs of the army.

4.37 Airborne Surveillance: The purpose of airborne surveillance is to secure the maximum data possible about items of military interest between the main line of resistance and an arbitrary distance into enemy territory, set as 200 miles, in accordance with ranges of missiles currently planned. There will be different types of information desired on different occasions, and specific problems will arise that require specialized equipment. Basically we think about three types of "missions" that will cover the majority of needs. These may require three separate radar systems, although some combination of function may be possible. These missions are (1) area surveillance, (2) spot surveillance, (3) motion surveillance.

4.371 Area surveillance is the exploration of the whole assigned enemy terrain to obtain a complete picture of all objects present for central evaluation. By its nature, tremendous amounts of data are obtained which can be recorded photographically either in the vehicle, or at a communications center after a data transmission process. Because of the volume of data, considerable human interpretation and comparison procedures will be needed.

The strip mapping radar seems outstandingly adapted to this problem. In this field the British have developed, at the Telecommunications Research Establishment as part of the "Red Setter" program, an x-band

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

4-46

side looking system which uses a 15-foot linear antenna array mounted in the fuselage of an aircraft. Data is presented in a photographic strip map. The system is intended for use as a navigational aid and limited production is under way. A k_a -band system using a somewhat longer antenna is under development for use in bombing.

In this country, The Maxson Company has been developing the APQ-38 for WADC which has two modified x-band APS-23 antennas back-to-back, gyro stabilized in roll and azimuth. By coordination with the APN-66 Doppler navigation radar which gives ground speed and yaw, the radar is oriented to look normal to the direction of flight. At present, the radar sweeps are stored on a storage tube which is read off at a slower rate which is within the capabilities of a facsimile recording system. The Maxson apparatus incorporates a monopulse form of beam sharpening which tends to blank out targets not exactly on the antenna axis.

The Philco Corporation also has a side looking radar program, with BuAer. The chief emphasis in this program, however, is extremely low side lobes so that an aircraft scanning large areas of sea will give no warning to a surface craft or surfaced submarine before it is scanned. This points up the existence of a similar advantage over land in minimizing the effectiveness of RCM. A flyable prototype is expected by 1954.

A contemplated future version of a strip mapping radar, to operate at K_u -band has been assigned the tentative nomenclature APQ-53. This may use a 16 ft. long linear array antenna that is under development.

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

4-47

The RCA "Nighthawk" radar development for BuAer, still in early stages of development, is included here in area surveillance because its parameters make it very suitable for rapid covering of large areas in fine detail, although it is not well adapted to long continued survey of one spot. It uses a .01 us pulse, operates at k_a -band with a PRF of 15 kc, and has a beamwidth of 0.4 degrees. A relatively narrow sector is scanned at 20 cycles per second thus providing substantially a bright display. The Nighthawk is intended for "hunter-killer" operation. It will examine any small sector of interest in considerable detail, and if necessary, it will direct "killer" aircraft to any suspicious targets.

Radars of the rotatable type with PPI presentation are usable for area surveillance. When so used the whole area of concern is mapped by a series of PPI scope photographs, taken on every scan, or on scans sufficiently frequent in time to give enough overlap. Since those radars are also suitable for spot surveillance of a limited area, they are discussed under that heading.

4.372 Spot surveillance. The requirement for multiple looks at a particular target area is foreseen. In rugged terrain this may be required so as to find aspects from which a particular suspect location is visible, without obstruction by terrain features. As indicated in Section 4.2 some methods of identification may require that the operator (either in the vehicle or by remote control) concentrate his attention on a particular target spot. Where "events" are expected in a particular

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

4-48

area but cannot be predicted exactly in time, such as may be true for burst spotting or damage reconnaissance due to guided missiles or atomic artillery, spot surveillance for a period of time may be needed. This period may be seconds, minutes, or hours. Strip mapping or forward looking radars are not particularly well adapted for this source.

Many radars have been made for mapping, charting, bombing, and search, which fill, to some extent, the needs here. The APQ-13, x-band radar, with 36" dish or with 60" pillbox and dish was used in World War II and is still widely used. The total weight of the system is about 300 lbs. The APS-23 is a newer x-band radar, with a 60" cylindrical paraboloid and pillbox, which is now in production. The APS-43 is a k_u band version of the APS-23, a few prototypes having been built. The APS-31 and APS-44 are important airborne radar equipments. The APS-23 particularly has been used as the starting point for many subsequent experimental developments, for example: in wide dynamic range presentation; for monopulse (APQ-45); for strip mapping (APQ-59); and for moving target indication (APS-27).

4.373 Motion surveillance - it has been emphasized repeatedly throughout this report that the one class of target of great importance to the military that is perhaps better accomplished by radar methods than by any other means is the detection of moving targets. MTI work was done in the last years of World War II at the MIT Radiation Laboratory and has since been tried on many radar systems. The designation of the two prototype equipments started at MIT were the APS-26 (Butterfly)

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

4-49

and the APS-27 (Firefly).

Butterfly, as described under techniques, basically has one storage means, either the ear or a bank of filters; it allows the examination of one range gated radar element at a time; and achieves considerable sensitivity by integrating many pulses, to note any non-d-c, or audio components. It was not carried very far during World War II, but has been explored and flight tested at the Control Systems Laboratory at the University of Illinois within the past year. Because of limitations in the usable sector imposed by Doppler beating internally within the clutter when the antenna beam deviates far from the ground track, the preferred implementation seems to be a forward looking, wide beam, non-scanning radar, which can be flown along roads or down valleys to detect and locate moving targets. It is anticipated in the current program at CSL that the location of the moving targets can best be done by a knowledge of the location of the search aircraft. The combination of an MSQ-1 (x-band SCR 584) and APW-11 beacon could be used to determine the location of the aircraft in map coordinates. The Air Force will build and have Delco test 10 Butterfly type systems to be known as the APS-58 for service testing using the APQ-13 radar as a base; the weight of the system is estimated as 300-400 lbs. It is claimed that an airborne Butterfly system can detect target motions as low as 1/2 mph along the ground track. Aural detection and easy transmission of data back to base over a voice channel are prominent advantages. Research on improved display includes SINUFLY and Doppler B scope work at CSL.

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

4-50

For ground based application this has been discussed in sections 4.2 and 4.6.

The other MIT Radiation Laboratory prototype system, the Firefly, was a non-coherent MIT system, with pulse to pulse subtraction using a delay line. It has been the subject of several experimental improvement programs in recent years including:

- a. APS-27 (XA3): Flight tested from Fall of 1950 to Spring of 1951, based on the APQ-13 radar.
- b. APS-27 (XA5): Thirteen systems delivered and flight tested, starting in November 1951. Based on APS-23 radar, and uses mercury delay lines. Work done by Laboratory for Electronics.
- c. APS-27 (XA6): Being built by Bell Telephone Laboratories, using quartz lines and the APS-23 radar. Will conform to ANEL9 standard environmental specifications.
- d. APS-27 (XA7): Being developed by LFE. Uses quartz delay lines, conforms to ANEL9 specs, and is built to operate as part of K-5 bombing system. Should be complete by early 1954 for installation in a RB-66 for low altitude bombing against moving targets. Will weigh about 600 lbs. total installed.
- e. SARTACK - This is a light weight area or spot surveillance radar, with an objective weight of 200 lbs. It is a k_u band set based on The Convair APS-48 unattended missile radar, and will incorporate quartz delay line AMTI. Antenna sizes of 45" and 30" are being studied. Full scale development will get under way in 1953. By virtue of its

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

4-51

premises, namely, light weight and a radar originally designed to operate unattended, this development should be followed carefully for possible mounting in a drone, as part of the TEOTA program.

f. The Navy (BuAer) has a development program to add AMTI to its long range search systems such as the APS-20B. This is at present in an early stage.

The performance of the pulse to pulse subtraction type of AMTI is quite good for fast moving targets but is very poor in sensitivity for slowly moving targets. Targets moving at less than 5 knots are difficult to see even under optimum conditions. Typical dead ahead (on the ground track) ranges quoted are: trains, convoys, or heavy highway traffic, with radial velocity component over 8 knots can be detected up to about 22 miles; 2½ ton trucks at 8 knots or more, about 10-12 miles; jeep at 10-15 knots, about 5-6 mile range. For a plane moving at 150 knots, the performance becomes appreciably poorer at about 60° from the ground track. For a plane moving at 500 knots, the degradation is appreciable at 7.5° off the ground track. New techniques referred to in section 4.2 may alleviate this situation and permit 360° operation of AMTI.

A system for motion surveillance is here proposed for serious consideration. It is based on the premise that continuous surveillance is possible from behind one's own lines. With such a system the livability of the vehicle may be several orders of magnitude greater than for direct surveillance over enemy territory. For such surveillance on a

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

4-52

short range basis, a light weight radar, possibly SARTACK, should be considered, mounted on a demountable tower, or held by a balloon or even a guyed helicopter at an altitude of 100-1000 feet. For long range surveillance over an area possibly as great as 200 miles square, the type of radar now used for AEW or ASW, such as the APS20B might be used in a large aircraft, perhaps of the size of the Constellation. For the system that is visualized, it would be necessary to develop the means of making AMTI useful in the sidewise direction by cancelling internal clutter motion due to plane velocity, as discussed in section 4.2. With this modification on say the APS-20B with 4 Megawatts at S-band, the plane could fly a continuous vigil parallel to the main line of resistance, and some 10-20 miles back from the front and at an altitude of 40,000 feet or more, to permit seeing 200 miles in level terrain. At the greatest distances, only the largest type of movement would be visible - trains, high speed convoys, etc. At closer ranges smaller targets will be visible. It is felt that this system would circumvent the enemy tactic of pulling off the road and stopping whenever a surveillance plane was detected. Such a radar would have considerable usefulness despite the fact that for the great ranges and the large beamwidth, the resolution would not be particularly high.

Both the long range and short range motion surveillance provide means for receiving other types of information from enemy terrain by use of beacons, either active or passive, that are shot, dropped or planted in enemy territory, to pick up acoustic or other sensory infor-

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

mation and broadcast it when interrogated. When a beacon is detected during normal search, the radar can searchlight it and detect the nature of sensory information signals it is sending, either by range gating or by using a photo-electric probe on the PPI.

4.4 Proposed Program:

The discussion in section 4.2 of the current state of available radar techniques, and the discussion in section 4.3 which indicates some of the systems in either preliminary or advanced stages of development, serves to show that considerable progress has been made in providing equipments of advanced design to fulfill certain military requirements. Considerable ingenuity has been shown in developing new techniques for more effectively meeting these requirements. While really advanced research in radar has not received enough emphasis and funding to exploit rapidly many new techniques, it appears that these advanced techniques ultimately reflect themselves in equipment and instrument design, or else serve as the impetus for further development.

It is strongly urged that all existing techniques pertaining to radar identification be very carefully examined to explore their inherent capabilities and limitations. Attention is directed to the fact that some of these techniques have been explored only from considerations of particular applications, often from the point of view of a given set of requirements, and that an inadequate process for one application might prove to be highly feasible for a second application. Then too, particular developments which may be directed toward a given ob-

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

4-54

jective, might also be adaptable to other needs. As a case in point, it is noted that the Doppler techniques have been reasonably well explored and utilized in the past, yet two techniques for radar mapping, the recent one by Dr. C. W. Sherwin and one included herein by Mr. W. Hausz, indicate that applications involving extension of known techniques are still possible. Above all, the study of known techniques should be made in the light of the specific battlefield surveillance problem.

A number of specific recommendations will be listed below. These include recommendations for research, advanced development, and development, in many cases to be followed by procurement programs. These do not purport to be either complete or final, but are designed to point the direction of work so that ultimately the scientific effort so brought to bear will lead specifically to equipment which contributes to the general surveillance problem of the battlefield.

4.41 Ground-based Problems: The term "ground-based" is to be very loosely interpreted here as meaning almost any equipment which is mounted on the ground or in non-flying carriers. It is possible, for the present considerations to use the same general headings as in section 4.3. For convenience in interpreting the recommended program in the light of the existing status, Table 4.41 is attached. This table summarizes pertinent equipment programs, in both production and development phases.

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

4-55

a. Personnel and Vehicle Detection

0 to 2 year period

1. Develop and produce high power versions of the AN/PPS-1.

2. Program for the conversion of light-weight radar equipments, such as beacons, into pulsed-radar systems.

3. Inclusion of Butterfly in 2.

4. Procurement program of interim Truckfly equipment.

2 to 4 year period

1. Production of the most feasible developments above.

2. Measurement, for different frequencies and polarizations of the echoing area of man.

3. As in 2, but for different military implements of man.

4. Development of light weight pulse Doppler equipment for personnel use.

5. Develop coherent sources of high power radiation.

6. Explore use of beacons on vehicles for location and identification, with means for communication on beacon channel.

4 + years

1. Applications of correlation techniques.

2. Develop equipment on basis of studies during intermediate periods.

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

4-56

b. Mortar Location

2 to 4 year period

1. Explore new avenues for the development of light-weight equipment.

c. Machine Gun and Small Arms

2 to 4 years

1. Study and experiments to assess all possible techniques.

d. Artillery Location

2 to 4 years

1. Increased emphasis to insure availability of AN/TPQ-5.
2. Develop new techniques to reduce complexity of equipment.

4.42 Airborne Systems: Airborne systems are required for three general classes of surveillance problems, namely, area surveillance, spot surveillance, and motion surveillance. Programs for each are discussed. In this connection, Table 4.42 lists some of the more important current programs that possess inherent interest to the TEOTA program.

a. Area Surveillance

0 to 2 years

1. Support and procurement of Maxson APQ-38 equipments.
2. Procurement of PPI type mapping radars at k_u band.

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

4-57

2 to 4 years

1. Evaluation and comparison of Nighthawk, APQ-38, APQ-53 for area surveillance.
2. Support the development of equipment to test and evaluate the two methods proposed of ground mapping by Doppler analysis.
3. Develop and procure side-looking radar of very high resolution by very short pulse and narrow beams (say ku band and 15 foot antenna).
4. Develop equipment for continuous strip photography.
5. Develop equipment for electronic comparison by superposition of radar strip records and photo-reconnaissance records.
6. Develop microwave sources in the 3.5 mm band.
7. Theoretical and experimental study of ground clutter, from frequency and polarization viewpoints, with techniques for optimum identification.
8. Exploration of advantages of polychromatic radar.

4 1/2 years

1. Equipment development at 4.3 mm.
2. Produce side-looking radar of various advanced types.
3. Prototype development of thermal microwave system if evaluation shows it feasible.

b. Spot Surveillance

0 to 2 years

1. Procurement of APS-23 radars or their successor for

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

4-58

spot surveillance purposes.

2 to 4 years

1. Development and procurement of the best equipment available within this time scale - short pulse, narrow beam, wide dynamic range.

2. Study of "signature spectrum" characteristics of radar targets.

3. Foster techniques for stereoscopic viewing of PPI scans made several minutes apart.

4. Explore use of polychromatic radar for detection and identification.

5. Display methods for high resolution techniques under 1.

6. Explore modifications to permit searchlighting or narrow sector scanning of a chosen area independent of aircraft motion.

7. Systems development of navigation information integrated with radar information for most accurate location of a target.

4 + years

1. Develop and process integrated systems incorporating as much as possible of the successful developments in the 2-4 year period.

c. Motion Surveillance

0 to 2 years

1. Procurement of Butterfly kits for existing bombing

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

4-59

or mapping radars.

2. Exploitation of Sinufly as an MTI technique.

3. Exploration of the system of continuous motion surveillance using a long range radar (such as the APS-20-B) with AMTI, which is flown continuously over our own lines.

2 to 4 years

1. Coherent sources of high power radiation.

2. Application of AMTI to side-looking radars.

4 / years

1. Equipment development and procurement of advanced types.

4.43 Techniques for Identification: Many of the techniques for identification have been programmed in sections 4.2 and 4.3. There are a number of other techniques which have applicability for many systems, which are listed below, and which are recommended for exploration.

a. Dynamic Range

0 to 4 years

1. Examine the applicability of television techniques for the improvement of dynamic range to radar displays.

2. The use of transparent phosphors as a means of extending the contrast range.

3. Display of radar information by means other than through the use of cathode ray tubes.

4. Applicability of color tubes for the display of radar information.

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

4-60

TABLE 4.41
RADAR SYSTEMS
STATUS
(Ground Based)

Function	Equipment	Maximum Range	Status	Eqpts: on Order	Delivery
Personnel and moving vehicle detention	AN/PSS-6	300 yds	P	50	1953
	AN/PPS-1 (XE)	2000 yds	D	-	:Field Test 1953
	Truckfly	2000/25000 yds	D	-	:Eqpt now in field test
	Correlation		R	-	-
	Polarization studies		R	-	-
	Doppler B-scope		D	-	-
	Sinufly		R,D	-	-
Mortar Location	AN/MPQ-10	7000 yds	P	550	:10 Oct 1952; 25/mo from Mar 1953
	AN/MPQ-7	7000 yds	D	-	:Field trials 1953
	AN-MPQ-4	7000 yds	PD	-	: 1955
	AN-KPQ-1		D	-	:First trial 1953
Artillery Location	AN/TPQ-5	24000 yds	PD	-	: 1955
	AN-MPQ-21(XE-1)	20000 yds	PD	15	: 1953
	AN/MPQ-21		D	40e	: 1954-55
Machine Gun	-		-		
Weather (cloud base and top)	AN/MPQ-9				
	AN/GPS-9	200 mi			:Tested during 1951
	AN/TPQ-6				:Test during 1952

Status Key

P - Production in process
PD - Production development
D - Development
R - Research
e - expected

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

4-61

TABLE 4.42

AIRBORNE RADAR SYSTEMS

Function	Equipment	Range	Status	Eqpts on Order	Delivery
Area Sur-veillance - side looking	APQ-38 APQ-53 Philco	50 miles	D D D		Test 1952 - Prototype 1954
Front Looking	Night Hawk				Prototype 1954
Spot sur-veillance	APQ-13 APS-23 APS-31 APS-43 APS-44 APS-45 APS-56 Sartaack	50 miles	PD D D		Available Available 1953 Model 1953 Test 1953
Moving Target	APS-27 (XA) APS-27(XA-5,6 APS-27(XA-7 APS-58 Modification APS-20B			10	Some versions tested from 1950 Test 1953 Test 1954 Test 1953 - -
Weather	APQ-39 APQ-40				Test 1953

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

CHAPTER 5

PHOTO-ELECTRIC SYSTEMS

5.1 Introduction:

This chapter delineates its discussion from the photographic field by emphasizing techniques which permit the immediate and continuous flow of intelligence. It has recognized the limitations imposed on these techniques by fog, smoke or dust, and looks to the radar field to attack such problems. Differentiation from the infrared field is less pronounced, and some of this chapter relates to infrared.

It was recognized that the contemporary television art could provide useful reconnaissance tools at a relatively early date, and might be expected to have a pronounced effect on night warfare. One of the principal needs is the source of illuminating energy. In the optical and near infrared fields, there do not yet exist devices of sufficient sensitivity to react adequately in a passive manner except in daylight. The useful energy would, therefore, have to be supplied either as continuous illumination (primarily daylight) or as scanned illumination (some form of searchlighting). Night operation is believed feasible at the present time only with intermittent illumination, if the source of energy is not to be placed in jeopardy. A possible exception is envisaged in the proposed rocket reconnaissance system where the short duration of flight (2 minutes) makes feasible the generation of a light scanning beam from the rocket.

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

5-2

It has been ascertained that great strides have been made by Army Ordnance in the development of short duration flash cartridges. However, development is still required to project and fuze these flash cartridges from artillery weapons. Consequently, night reconnaissance, in addition to several engineering television developments, is also dependent upon the development of flash shells, presumably by the Ordnance people.

A major fraction of the useful television reconnaissance appears to be airborne in nature. This immediately leads to the requirement for airborne platforms. It is fundamental that to see well and widely, a vantage point of elevation is imperative. Equally important for long range television reconnaissance is the need for elevated or airborne relay platforms, both to pass back the video intelligence and to accomplish telemetering control of the camera and its vehicle.

The essential techniques of the television art are well known, and there appears to be no merit in a technical discussion of these at this time. Of course, any discussion of conceptual character will be fully annotated. What is intended, is a discussion of the elements of systems for particular military objectives. This will be followed by a discussion and cataloging of equipment and components available currently. This will point out the gaps which appear to exist, and so will lead to the pertinent recommendations for programs which will be designed to provide the requisite information, data, and equipments.

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

5-3

5.2 Systems and Special Components

The systems to be discussed do not necessarily represent new conceptions in photoelectric reconnaissance systems. In fact, it calls upon a number of television projects and equipments which are either used in, or applicable to the problems under survey. However, the emphasis is directed to the battlefield problem, the value of any given technique or equipment being examined in the light of the surveillance problem being discussed.

5.21 Portable Television System for the Infantry. The infantry might find a simple portable television camera which can be carried to observation posts or on patrols a most useful device. Such an equipment would enhance, with accurate visual details and with continuity, the present verbal reporting of data. In daylight use it would relay to near or remote commands a television picture of all that the observer sees. At night, with the aid of flash shell illumination, it would provide periodic still pictures which can be stored or photographed at the command post and examined. This latter use is particularly valuable, since present nocturnal observation data is derived almost completely by ear.

Recently, a developmental model of a portable television station for broadcast use was demonstrated by the Radio Corporation of America. It has been called a "walkie-lookie". This equipment is a pack-carried, completely portable, battery-operated pick-up station with its own synchronizing generator, video and sound channels and radio link to

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

5-4

and from a control point. A vidicon pick-up tube is used. The complete pack, including power supply, weighs 50 pounds and the separate camera unit about 8 pounds. The system has demonstrated a reliable range of 1/4 of a mile with a radio link at 500 megacycle. The battery capacity permits continuous operation for about one and one-half hours on a single charge.

In its present form, this equipment does not meet the exacting requirements of the military for a pack-carried patrol television system. It does, however, constitute a basis for an evaluation study of man-carried television systems for reconnaissance use.

5.22 Helicopter Television Mortar Locator System. Enemy mortars can be located from their firing flash by an observer at sufficient altitude. This is now done mainly in daylight by a trained artillery expert in a light plane who reports by radio telephone. It appears possible to replace the vulnerable artillery expert by an elevated electronic camera which will send by radio a series of pictures to the fire direction center showing the enemy mortar flashes and their own shell flashes. The artillery expert will be at the fire direction center where he can operate directly from the received pictures. The camera can be carried aloft by a helicopter, a drone, a balloon or in some cases a tower.

The proposed mortar locating system is premised on the use of phosphorous indicator shells by day and long-glowing fusee shells by night. Two or three indicator shells

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

are laid down in the general vicinity of the enemy mortar. The elevated television camera is directed by telemeter control to look at these persistent indicators. The artilleryman has related each indicator to a set of fire coordinates for the field piece which fired the indicator shell. When the flash of the enemy mortar is next seen on the television screen, its relative location among the indicator shells is interpolated to give the desired fire coordinates. The television camera platform does not need to remain stable, provided only that the camera can be directed to contain the indicators within its field of view.

In the alternate, but more limited concept, triggerable light beacons replace the indicator shells. The exact geographical position of the beacons can be known. In general, the beacons must be on the fringe of friendly territory and therefore remote from the mortar. However, the interpolation of coordinates can be aided by using two geometrically related cameras, one to view the near beacons, the other to see the mortar. A modification might be an optical system accomplishing the same result in the two halves of the field of view of a single camera. This system is further complicated by the need for triggering when the mortar flash is seen. However, this approach, if combined with a storage camera tube and a stable platform, need not continuously transmit data, and is therefore more secure.

The most challenging phase of development in the proposed mortar location system concerns the ultimate perfection of a drone airborne

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

platform. A small unmanned helicopter has been considered desirable because of its hovering features. Low radar cross-section can be expected, and the visible motor exhaust can possibly be removed by the judicious use of newer catalysts. An elaborate two-way telemeter link to the drone is needed, but is within the scope of present art.

An image orthicon television system and video link will require a specific engineering development, but needs no extension of art to provide an immediately useful system.

The proposed system is also directly applicable to general reconnaissance use - both day and night (with flash shell illumination).

5.23 Television Reconnaissance from Drone Aircraft. Surveillance of enemy activity in supporting areas several miles behind the immediate battle zones, particularly at night is an important and difficult problem in reconnaissance. Photo-reconnaissance using flash illumination with subsequent photo-interpretation provides information in great detail of a multitude of night-time activities such as concentrations of men and material and mass movements toward the front lines of vehicles and armor along main supply lines. Such activity is usually in evidence immediately prior to large scale offensive action, and speed in gathering information concerning it is of utmost importance. This requirement leads to the use of airborne television systems for day and night reconnaissance. Because of the hazards of aircraft operation in these areas, the requirement that the aircraft be unmanned and recoverable, i.e., drone aircraft, is apparent.

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

5-7

Sources of target illumination must be included in order to provide useful night-time surveillance.

Television equipment for the general uses of airborne reconnaissance has been developed in the Air Forces, and its practicability has been demonstrated for day-time operations in aircraft such as the RF-80. Furthermore, small, lightweight drone aircraft are now in existence and appear to be suitable vehicles for specially developed television systems. Illumination sources in the form of flash cartridges for intermittent illumination intended for night photography are available and should be adaptable for use with television systems. Present developments in the field of infrared are applicable.

5.24 Rocket Reconnaissance System. The requirement for reconnaissance data in the range from 0-10 miles behind the enemy lines may be partially fulfilled by the use of a rocket carrying a simple line scanning photo-cell pick-up device, and transmitting video data. In the simplest form, no control is exercised on the rocket after firing.

A typical vehicle might consist of a rotation - stabilized four inch diameter rocket which will follow a very shallow trajectory with the altitude varying between 500 to 1,000 feet over a range up to 10 miles. Such a vehicle, travelling at 1,000 feet per second, will cover a 10 mile range in 60 seconds, and so be very difficult to intercept. Catapult or booster launching is envisaged.

The photo-electric camera sweeps laterally across the terrain by means of a rotating mirror which successively reflects each ground

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

element onto a photo-multiplier cell. As the rocket advances, successive scanned "lines" are converted to a video signal, transmitted to the base receiver, and photographed from a television tube with a line scan film recorder. The single brief flight, therefore, yields a strip photograph extending out over enemy territory.

For the parameters considered below, the picture will resolve a four foot square of terrain immediately beneath the missile track (altitude 1000 feet). The necessary 45° dove prism rotating at 15,000 rpm may be a rotating rocket nose, or it may look downward only through a transparent aperture in the cylindrical rocket wall, or it may be in the tail, if the prime power plant is placed at the tip of stub wings to avoid exhaust scintillation. Powder charge acceleration of the rotating mirror may be employed. A 3" lens focuses onto the photo-multiplier. The link transmitter requires a 200 kc video bandwidth. The electrical power plant will probably resemble the powder charge generator used in the Sidewinder missile.

A ground illumination of 10 foot lamberts is required to provide a S/N ratio of 30 db. This permits dawn to dusk day-light use. For night operation a "flying spot" light beam would probably be generated in the rocket. This requires development, but it can be computed that 5 lbs. of magnesium would provide an adequate 60° cone of illumination for the 60 seconds of flight.

5.25 Tank Television System. A tank conveyed reconnaissance television system is feasible, and its effective military use should be

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

5-9

carefully studied. It is known that tanks do not generally operate in exposed locations which command a wide field of observation, and would not be operated with self-illumination at night. However, the possibility of conducting an armored television patrol far into enemy territory exists, and so might well be considered.

A major project, now nearing completion for the Signal Corps by the DuMont Laboratories, provides a television system for use in a remote controlled T-41 tank. The television equipment has the parameters listed in Sec. 5.3. This equipment can soon be evaluated as a reconnaissance device.

5.26 Storage Camera Tube Development. In order to derive the maximum benefit from various systems of reconnaissance using photoelectric techniques, the development of camera tubes having fast response and long storage time capabilities is essential. To be of maximum utility, the tube shall be capable of functioning in both normal daylight as a conventional high-sensitivity pick-up tube at normal line and field scan rates and as a long storage tube. It will permit either the transmission of intelligence at reduced bandwidth, or the storage of elements of information occurring at separated time intervals for simultaneous transmission and presentation. The following characteristics should be made available:

- A. Extremely fast charging time to allow the recording of a single occurrence or of very high speed phenomena of short duration.

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

- B. Available storage time of long duration of either delayed transmission of information or relatively long time transmission at restricted bandwidth.
- C. Short erasure time to avoid the effects of previously stored information.
- D. Capability of storage of occurrences separated by time intervals for simultaneous viewing.
- E. Various types of spectral response with particular attention paid to the infrared region.

The above characteristics are within the reach of current art.

At the present time, various scan-converting storage tubes are available or under development, among which are the RCA Graphecon and Metrichon. Other image converter and recording tubes are under development at Farnsworth and Raytheon. Another line of attack on the problem which has been suggested is the combination of a present storage image converter tube (Signal Corps Contract DA-36-039 SC-42510) and an image dissector in the same envelope. In such a tube, the storage screen would be a perforated insulator upon which the electron image from a photo-sensitive cathode has written on it, by secondary emission, a charge distribution corresponding electrically to the original scene and acts in a fashion similar to a triode grid with a distributed potential. A source of electrons from a thermionic or photo-electric cathode penetrating the holes in the insulator screen would be scanned past a collecting aperture followed by an electron multiplier, thus

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

resulting in a video signal.

5.27 High Resolution Camera Tube and Optics. Photo-electric reconnaissance systems based on the use of present pick-up tubes are limited in their resolution capabilities as compared with photo-reconnaissance systems. In spite of this limitation, the inherent advantage of speed in data gathering and dissemination makes this technique immediately useful. However, as television techniques become an increasingly vital part of battlefield reconnaissance, the demand for higher resolution, both from the standpoint of presentation or reasonable detail within a wide field of view and extreme detail over a more restricted viewing angle will make the requirement for higher resolution pick-up tubes and better optical systems mandatory. Development of such systems puts additional bandwidth requirements upon the system as a whole unless slower transmission rates are employed. Thus, for maximum usability, pick-up tubes having higher resolution must of necessity be capable of increased storage times. This increased storage time introduces related optical and mechanical problems of image immobilization for many airborne uses.

It has been reported that a 2000 to 3000 line resolution camera is feasible at the present time, primarily by an increase in tube size. For tubes of increased size, problems in shading and field curvature would have to be solved and the correspondingly high resolution optics would have to be developed.

5.28 Multi-Lens Optical Development. A multiple lens optical system

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

5-12

can be used to provide wider angle of coverage for a television camera tube of given resolution (fixed size and structure of image scanning area), or inversely to provide higher resolution for a fixed width of viewing angle. Rate of acquisition of intelligence is, of course, reduced. Multiple lens optics perform the same operation that turning the camera or rotating a mirror can perform. Essentially, it breaks up the televised scene, so that various parts of the scene are caused to successively occupy the entire mosaic. The advantage of the multiple lens optical system lies in its ability to provide an angular scan at a very high equivalent angular velocity without introducing motion smear or requiring large acceleration and deceleration forces. It is applicable to a high-speed-aerial reconnaissance television system, and may also be used in high rate facsimile transmission.

The main problems encountered in a multiple lens optical system are: (1) the effect of field angle on illumination according to the well-known cosine fourth power law which produces non-uniform illumination across the photo-cathode; and (2) the necessity for matching and mounting multiple lenses which have nearly the same focal length.

In one conception three lenses might be arranged side-by-side so that each focuses a separate portion of adjacent scenes upon the full mosaic screen of a television camera tube. A rotating aperture then successively admits the ray bundle from each lens for a time long enough to permit scanning of a complete frame within the camera tube.

Dr. Brian O'Brian, of the University of Rochester (JSMPE, Jan. 1949),

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

5-13

has developed another type of non-moving optics which is particularly applicable to line scanning. By a very special lens conformation, a group of side-by-side areas of the televised scene are focused one-beneath-another on the camera screen, thereby more effectively utilizing the active screen area. It is probable that other optical arrangements will suggest themselves for particular uses. In all cases an additional synchronizing signal must be sent to an inverse optical device at the receiver in order to recover the intelligence.

5.3 Contemporary State of the Art

There are a multitude of projects and equipments which are either used in or applicable to photo-electric systems. These are discussed below under three headings:

5.31 Directly applicable projects.

5.32 Related developments.

5.33 Battlefield illuminants.

5.31 Directly applicable projects.

5.311 Signal Corps Program (Coles Signal Laboratory)

1. Vehicular Ground Television Systems (DuMont). An extensive study was undertaken of the application of television to the guidance of ground vehicles and to the relaying of reconnaissance information. The first phase of this program (Contract W36-039 sc 38231) consisted of a theoretical study of the optimum characteristics of systems for ground-to-ground television, with suggestions for airborne relay stations, as well as treatment of stereoscopy, and color vs.

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

monochrome. The second phase (Contract DA36-039 sc 138) was for the development of experimental equipment providing a remotely controlled television system of a laboratory nature. The third phase (Contract DA36-039 sc 15349) for tactical television equipment provides for a single camera television system for a remote controlled armored vehicle with means for remote control of the electronic equipment from a base station. The equipment provides the triple functions of guidance, surveillance and limited fire control. Experimental apparatus is to be installed in a T-41 tank. The system makes use of a type 5820 image orthicon, transmits a 525 line picture at 20 frames per second with 2 to 1 interlace. The transmitter is 500 watts peak and provides for six channels each of 5 mc. bandwidth in the 470-500 mc. band.

2. Modification of Block III Systems for Various Applications. Developments have been carried out for remote-controlled television camera systems for operation in slow speed vehicles and for certain operations associated with application of these vehicles. Included in these studies are remote control of camera in elevation and azimuth, optical focus, filter and electrical parameters of pickup tubes. Six systems were engineered, three with vidicon and three with iconoscope type tubes. Both the Block III system and the vidicon camera were modified for operation at 50 fields, non-interlaced, with horizontal scanning frequency of 14,000 cps. Vidicon camera employed a 1-inch, f1.5 lens, iconoscope camera an 8.5 inch f4.5 lens.

A Block III system was installed in an Army liaison type plane for

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

5-15

demonstration and study. This was modified to operate at 50 frames to reduce highlight flicker. The number of lines were reduced from 330 to 280 in order to maintain the same bandwidth requirement for the same horizontal resolution. Aspect ratio was changed from 4/3 to 5/3 in order to maintain the same vertical resolution.

A Block III image orthicon camera was modified for operation with a standard commercial synchronizing generator. Camera operating controls were made remote from camera. The camera lens mount was modified to accept the standard TV 50mm., 90mm., and 135mm. lenses. Transmitter and receiver were modified for improved frequency response and AGC characteristics.

3. Television System for Radar Applications. A system was designed to supply radar operators with optical information within the close range "blind area" of a radar set to function also as a remote data transmission source, and to provide simultaneous photographic recording of a multiplicity of data. Two Block III television cameras and monitors were modified for these purposes.

4. High Speed Facsimile (RCA). In connection with a study of employment of facsimile over the wide band facilities to be made available to the Army, RCA has constructed a high speed system. Using multiplex techniques, the system can transmit 8" by 10" copy at fax definition of 120 lines per inch over 1, 2, or 4, 48 kc channels. For 4 channel use, copy can be transmitted in 7 seconds.

5. High Definition Systems. A high definition camera chain

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

5-16

and presentation equipment having switching options of 525 or 735 vertical scanning lines and better than 700 lines of limiting horizontal resolution is under development. It was used to determine the value of employing resolutions higher than commercially available. It may be useful in determining resolutions required for long and short range reconnaissance.

5.312 Air Forces Program as Related to Reconnaissance.

1. Television Systems for Remote Control of Aircraft. Airborne camera equipment with air to ground relay links both AM and FM have been developed.

(a) AM System

AN/AXT-10 (RCA)
AN/AXR-8 (Philco)

(b) FM System (Philco)

AN/AXT-12
AN/AXR-10

2. High Speed Airborne Reconnaissance System (Philco) Contract No. AF 33(038)-7490. A comprehensive study of the problem of television reconnaissance using high speed planes is being made. The ultimate aim of the project is to write a detailed recommendation for the development of an experimental model of an airborne television system to be capable of picking up, relaying, recording and displaying reconnaissance from high speed aircraft operating at altitudes above five hundred feet.

3. Line-Scan Photocell Pickup Systems. Studies have been made of the possible usefulness of scanning the ground under an aircraft with

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

5-17

an optical system using photocell pickup for obtaining a video signal.

The following work has been carried out:

(a) Photographic Laboratory WADC, Haller, Raymond and Brown. An optical system, consisting of a spinning mirror, objective lens, variable aperture and field lens, is made to scan a succession of lines directly under but in a direction perpendicular to the motion of the aircraft. The field of view of the system is designed to be 120 deg. The variable aperture controls the resolution of the system. Light from the point being scanned instantaneously is focused on the photocathode of a 1P21 phototube which is followed by a logarithmic amplifier which compresses the range of sensitivity so it can be handled by a standard amplifier. The output is fed to a Phillips recording lamp which gives a light output which is a direct function of the phototube output. The data from the recording lamp is directly recorded on photographic film by means of a scanning system which is in phase with the ground scanning mirror. The speed of the scanning mirror is made to be a direct function of the speed of the aircraft in order to maintain an overall resolution comparable to the inherent resolution of the optical system. The data which is obtained is in the form of a strip map composed of a succession of single scan lines at a spacing dependent upon the aircraft velocity.

(b) Photographic Laboratory WADC, Boston University Optical Research Laboratory. The principles of this system are similar to those used by the Haller, Raymond-Brown group. The difference is in the use of a dove prism rather than a rotating mirror and the direct use of a

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

cathode ray tube instead of the Phillips recording lamp and photographic film technique.

4. Television Aid to Photographic Evaluation (CBS). An aid to evaluate and speed up color and black and white films taken during reconnaissance flights has been developed. The device derives a video signal from rolls of color or black and white positives or negatives of 9 1/2 by 9 1/2 size and permits viewing of a positive upon a television screen in color or black and white. Optical magnification of 1:1, 4:1, and 8:1 of any portion of the aerial photographs can be selected at will, at the same time making it possible to explore the entire photograph, providing a full view of the observed scene in 9 1/2 by 9 1/2 size. This device is primarily intended to speed up processing by avoiding an extra step in producing photoreversals and to give a new tool to the photo interpreter.

5.313 Navy Television Programs.

1. Amphibious Reconnaissance Television. BuAir, BuShips, (CBS). A color television system has recently been completed which is intended primarily for the purpose of airborne observation, from hovering aircraft, of amphibious landing operations, with a relay link from the observing aircraft back to the ships from which the operations are directed. It is expected, as one use, to explore the possibilities of camouflage detection with such a color system. The color camera is about the same size as the Block III black and white camera. The iris control and focus are remotely operated. The color system is the field sequential

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

5-19

type with 405 lines and 144 fields and the video signal is substantially flat to 10 mo. It has been suggested that for future use, the color frequency be reduced to 120 cps, since slight flicker at the receiving end would be of little consequence.

2. Facsimile Equipment. BuShips (RCA). Development has been completed of a high speed facsimile equipment with a bandwidth of about 100 kc. which can be used to transmit television screen photographs throughout a chain of command.

5.314 Developments in Completely Portable Television Equipment.

1. Man-Carried Television Station. (RCA) The "walkie-lookie" equipment, which has been discussed in Section 5.21, provides a light-weight vidicon camera to be carried by a man. The equipment is a pack carried, completely portable battery-operated pickup station with self-contained synchronizing generator, video and sound channels, and radio link to and from a control point. The complete pack, including power supply, weighs 50 pounds and the separate camera unit about 8 pounds. The system has demonstrated a reliable range of 1/4 mile with a 500 mc carrier. Battery capacity allows continuous operation for about 1 1/2 hours on a single charge.

5.32 Related Developments

5.321 Television systems.

1. Target designation systems. BuOrd (RCA). This is a 3-color television system for presenting radar information to the battery control officer and the local battery control officers. By means of a joy stick

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

5-20

and pip markers, targets can be designated for local battery firing and in turn, when targets have been acquired by local batteries, a distinctive pip is presented to the battery control officer. Fifteen equipments have been ordered for a services evaluation during 1953. Vidicon pickup tubes are contemplated.

2. Underwater Television. (BuShips). The objectives of this program are to produce television equipment for salvage operations, submarine rescue, maintenance of underwater installations, mine counter-measures (identification of ground mines), underwater weapons, development and test, and studies of marine biological life in connection with acoustic problems.

Present equipment is mounted in a cylindrical package 6" diam. and 2' long. 500 lines definition with 50 frames/sec. are currently employed.

5.322 Storage Tube Developments.

1. The Graphecon. The graphecon is a scan-converting storage tube of limited half-tone range. This tube is the most advanced of the RCA storage tubes and will be commercially available in 1953. It is capable of 400 line resolution and its storage time is 20 seconds with at least a 10:1 signal to noise ratio. This tube, despite its limited half-tone range is capable of pictorial reproduction. It finds its major use, however, as a radar-to-television scan converter.

2. The Metrichon. This is a scan-converting storage tube similar in application to the graphecon. The tube, now in the advanced development stage, has a full half-tone range, 400 line resolution, and storage

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

5-21

exceeding several minutes. It is useful where conversion of scan rates is desirable for subsequent transmission or viewing.

3. Direct View Storage Tube. Contract #W36-039sc44532. A tube has been developed in which video information can be stored and simultaneously viewed. In its present state, 250 line resolution on a 4" screen has been observed. Television writing speeds are obtained together with highlight brightnesses of 1000 ft.-lamberts. Storage time may be controlled from 0.1 sec. to more than 1 minute. Development is continuing on this tube to provide higher resolution and longer storage time.

4. Raytheon Storage Tube. The Raytheon recording tube is a storage tube having 400 line resolving power and full half-tone range which can operate at television writing speeds. Holding time without read-out is a week or more. Holding time for continuous read-out is over 25,000 read-outs. This tube has a single election gun which is used for read-out, write and erase. The present tube which is in pilot production has magnetic focus and deflection using a standard focus and deflection yoke. The tube can be designed for simultaneous read-out and write by using two independent election guns at opposite ends of the tube.

5.323 Infrared Pickup Tube Developments.

1. Infrared activity at RCA is being carried out under the following contracts:

(a) Infrared Pickup Tubes, Contract #AF33(038-13607)

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

5-22

- (b) Infrared Pickup Tubes, Contract #DA36-039-sc.200
- (c) Infrared Pickup Tubes, Contract #DA44-099-eng.-227
- (d) Infrared Pickup Tubes, Contract #Nober 52199
- (e) Infrared Research, Contract #DA44-099-eng.-168

The IR Image Orthicon

This tube has the usual photocathode replaced with a surface similar to that employed in the 1P25 image tube. The response is in the near infrared region, roughly less than 1.2 microns. With an f2 objective lens, this image orthicon has a range of 30 to 70 yards with continuous 30 watt IR source and up to 500 yards with a 1 kw source.

The IR Vidicon

This tube is a photoconductive tube. Present photoconductive materials respond in the intermediate IR spectrum where semi-passive imaging is possible (objects at elevated temperatures, such as jet exhausts may be seen). Passive IR television is felt to be feasible with photoconductive materials, but a practical tube for this purpose is not likely much before 1956.

Both the IR image orthicon and the IR Vidicon will respond to IR flashes of duration as short as a microsecond. However, since no frame storage would be possible, the sensitivity figures would be reduced by many orders of magnitude. The present photoconductive surfaces will hold a charge configuration for at least 1/15 second. Fundamentally, this period may be made much longer.

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

5-23

5.324 Miscellaneous Developments.

1. Universal Camera Control. A contract between DuMont and WADC provides for a camera control with various electronic motion stabilizing features. It has been designed primarily as an adjunct to photography but may have some applications to television airborne reconnaissance.

2. Bright Display System. Apparatus providing a bright display radar indicator system is nearing completion at DuMont for the CAA for installation at Indianapolis. The system involves the storage graphecon, permitting reproduction of low frame rate radar patterns at normal commercial television line and frame standards on 12 inch display units and 30 inch plotting units using high brightness P4 type tubes. A television flying system is used to generate map video information for mixing with the television radar video signals.

3. Teletranscriptions. Intermediate film recording of signals from the cathode ray tube is provided on teletranscriptions equipment using DuMont 7 inch cathode ray tube. Theater television intermediate film equipment has been constructed as well as equipment for commercial broadcast film recording, and equipment delivered to the Navy at Sands Point for recording of cathode ray tube signals.

4. Film Transport Mechanism. A continuous motion unit now in operation and being readied for commercial quantities provides for transmission and conversion of film materials for video signals at television rates, radar rates, and in accordance with other standards. The mechan-

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

5-24

ism requires no specific synchronizing between the electronic and mechanical systems. The machine can be used for both transmission and recording, or storage of data. The flying-spot scanner used in conjunction with this continuous Film Transport Mechanism is found to be very effective in rapid analysis of motion picture films, wherein gun camera film is developed as a negative, for example, and then by passage through this television equipment is viewed quickly as a positive presentation without the need for additional photographic printing processing steps. This method of positive display of pictures from negative film has been applied both to black-and-white and color photography.

5. Missile Instrumentation. Guided missiles become so complex when expected to do entirely robot self-directing that television methods are now being seriously considered to supplement or replace other complex controls. DuMont, under contract to the Navy Bureau of Aeronautics, is studying missile instrumentation standardization, and in this connection it is currently considering television techniques on these projects. The television apparatus for this missile program may prove to be readily adaptable to certain uses which would be considered by the Signal Corps.

6. Three Color Tubes. Advances in tri-color tubes in 5 inch size have been reported. Three-gun registration plate controlled tri-color cathode-ray tubes are in rather general use for color television experimentation. The 16-inch tubes and the 21-inch tubes provide picture viewing sizes commensurate with color television experimentation.

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

5-25

However, for aircraft developments using color techniques in display of television pictures, radar presentations and certain oscillographic indications, a smaller diameter cathode-ray tube is essential where space is limited.

Five-inch tri-color tubes using a finer dot structure than that provided in the 16-inch tubes have been made at DuMont.

7. Short Time Erasure PLO Screens. Under contract with the Navy, DuMont has produced dark trace tubes having controllable storage time. Such devices indicate promise for retention of television reconnaissance information. These tubes offer some potentialities similar to the storage tubes mentioned elsewhere in these reports, but offer the further advantage of giving a direct pictorial presentation as well as a controllable "holding characteristic".

8. Recording Window Cathode-ray Tubes. Where a record is desired of a bit of electrical information, there are many ways of providing "video recording". One method of potential interest is the electrostatic recording of the influence of a varying electron beam by means of certain chemically sensitive emulsions. A cathode-ray tube having a thin glass window has been constructed so that sensitive paper or other emulsion-carrying substances can pass over this thin window and thus be subjected to the influence of a scanning electron beam which also varies in intensity. DuMont has prepared such recording tubes. Modifications of these simple line scan tubes may be adapted for both the recording and the playback functions of video teltran-

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

5-26

scription.

5.33 Battlefield Illuminants.

Army Ordnance Pyrotechnic Cartridges

M-112	Night photography to 3500 ft.	in general use
T-102	Intended to replace M-112	test scheduled Dec. 1953
M-123	Night photography to 8500 ft.	drawing & specs. complete
T-103	Intended as replacement of M-123	test scheduled Jan. 1953

Photoflash Bombs. Flash bombs are available in various sizes.

They are heavier and require more elaborate launching equipment than the cartridges.

General Illumination.

- (a) Grenades and rifle grenades
- (b) Parachute and ground delivery by mortars
- (c) Artillery parachute flares
- (d) Plane delivered parachute flare
- (e) Searchlights

Other Luminous Sources

MK 1218 Infrared flasher, prototype due in 1954

Magnesium Burner--Has undergone evaluation tests.

Spot Marking by Artillery Delivered Illuminant. Various sizes of mortar and artillery shells for parachute delivery of illuminants are available. It might be possible to replace the parachute and illuminant with an illuminant and base ejection system which would release the illuminant upon impact. However, such a device does not exist and

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

5-27

would have to be developed.

The suggestion has been made that a WP smoke shell might have sufficient luminous content and not disperse too rapidly to function as a marker. Such a shell might be modified to contain a higher percentage of photoflash powder. Ballistics of smoke shells can be made to match very closely the ballistics of regular explosive shells in the same case size. Data on luminous content and its duration are not available and would have to be determined.

5.4 Recommendations and Discussion

A number of possible systems were discussed in Section 5.2, the basic concepts of the operation being the subject of the discussions. In order to explore these systems further, in some cases study programs must be undertaken, in others, equipment development is indicated. This section will discuss the necessary programs in much the same order as in Section 5.2.

5.41 Portable TV System for Infantry. A study program should be instituted to investigate, with the present "walkie-lookie", the basic concept of observation or patrol reconnaissance by television. Salient points of the program would be:

- A. The determination of the transmission rate necessary to provide field commanders with adequate information. This study might reveal advantages for low frame rate scanning (e.g., 10 frames per second) or possibly time shared scanning (e.g., one frame scanned every 5 seconds).

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

5-28

- B. To establish the minimum resolution acceptable. For example, consideration of the maximum field of view necessary would affect the resolution requirements.
- C. A consideration of display and recording means to be employed at rear headquarters. Such display techniques as a long persistence kinescope or a Direct Viewing Storage Tube together with recording by the LAND process or on magnetic tape are possibilities. These facilities will definitely influence the usefulness of such a reconnaissance tool.
- D. Possible requirements for airborne or elevated radio relay points.
- E. An investigation of existing ordnance illuminants, such as flare shells, and an evaluation of possible development of flash shells.
- F. To study the possibility of television pick-up in infrared regions to provide a continuous television picture at night.

A development program should then be authorized to produce a suitable portable device. The present "walkie-lookie" could be the starting point with improvements as noted below:

- A. Volume and power supply reduction through transistorizing.
- B. Increased range by means of:
 - 1. Higher transmitter power
 - 2. Improved antennas
 - 3. Lower frequency if bandwidth can be reduced

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

5-29

C. Provisions to accept a camera-tube capable of operating in the near and/or far infrared regions.

5.42 Helicopter Television Mortar Locator System. Several systems are discussed which are believed to possess merit as mortar locators. Owing to the fact that some of the principles are untried, the systems as defined may not be optimum for the purpose. What is required, therefore, is a study program, augmented by field measurements, to permit a more unique definition of the optimum system for this application. Moreover, since the airborne platform is an essential part of the proposed systems, the study phase can be paralleled with considerations of the airborne platform.

5.43 Television Reconnaissance from Drone Aircraft. It is recommended that a project be initiated immediately for the development of suitable television camera and relay equipment for operation in drone aircraft capable of flying up to fifty miles into enemy territory. The first phase of such a project could consider adaptation of present airborne television equipment installed in suitable aircraft for day-time operation for system evaluation and study. This should be concurrent with the study phase of a long range program for development of specific equipment for both day and night operation. The ultimate equipment should be small light weight and simple and should be applicable to the smallest possible type of drone capable of carrying it. Particular attention should be directed to the following major problems:

- (1) Proper choice of field scanning rates and synchronization

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

with flash illumination. The type of presentation (continuous or single frame) is involved here. These considerations are related to present camera tube and future storage camera tube development. It is believed at this time that camera tube scanning should be coordinated with the flash illumination and scanning should take place during the non-illuminated interval. Scanning rates should be such that information to be relayed back is presented in the form of single frame pictures with very little overlap. Illumination time of the pickup tube should be sufficiently short to prevent loss of detail due to motion, up to the resolution capabilities of the pick-up tube itself.

(2) A full investigation of present and future developments in illuminants, particularly in the infrared region should be made. It is felt that in the near future night-time operation could be possible with some form of flash cartridge (or other flash illumination scheme). Camera tubes should have high infrared sensitivity.

(3) Relay range, including the practicability of airborne relay stations should be thoroughly investigated.

(4) The general problem of navigation would necessarily represent a large portion of the effort.

(5) General characteristics of systems including the possibilities of remote control of synchronization for reducing size and weight of the equipment in the vehicle should be studied.

(6) Considerations involving the extension of the system to high speed penetration missiles should be studied.

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

5-31

It is believed, on the basis of presently developed equipment, that evaluation models of complete drone systems for daylight use can be made available by the early part of 1954, and that completely integrated systems designed for both day and night use can be made available for evaluation for 1956.

5.44 Rocket Reconnaissance System. One particular concept of a short range television reconnaissance system using a simplified line-scan photocell pickup and relay system in an expendable rocket as a vehicle was outlined in Sec. 5.24. It is recommended that a development program be undertaken to implement these basic concepts. Such a program might have three separate parts. (1) a study phase in which detailed system characteristics would be established, (2) development of a complete and integrated system consisting of a highly miniaturized and simplified pickup system and relay link for daylight operation, together with the development of suitable rockets or modification of existing rockets, (3) a longer range program, which by further exploitation of known sources of luminous energy, would lead to the possibility of both day and night operation.

5.45 Storage Camera Tube Development. In addition to their applicability to television systems, storage tubes possess tremendous importance in other fields. Certain of the moving target indicator techniques employed in radar (e.g., Sinufly) require the use of storage tubes. There is, of course, considerable effort now being applied to the development of storage tubes, the important programs being listed

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

5-32

in Section 5.322. Owing to its importance, it is desirable that additional effort be devoted to the development of storage camera tubes having sensitivity and resolution comparable to or exceeding present-day camera tubes. Attention should also be given to the development of infrared photo cathodes.

5.46 High Resolution Camera Tube and Optics. In order to provide the accessories for high resolution television systems, effort should be directed to the development of high resolution pick-up tubes and related optics, such devices having characteristics and sensitivity and storage suitable for the reconnaissance application. Because the full utility of a system might be realized only with restricted bandwidth, the tubes must maintain a storage at full resolution up to one second. High resolution should be at the expense of increased size only insofar as absolutely necessary, and full consideration should be given to any other possible means of increasing resolution.

5.47 Color Television for Reconnaissance. It is proposed that an evaluation project be established to explore the potentialities of color in future military reconnaissance television systems.

Valuable experience has been gained through a color television project which has just been completed for the Navy (BuAer and BuShips) (see Section 5.313), and also from actual operational knowledge gathered during a large number of outdoor pick-ups made with the CBS color television equipment and by others under broadcasting conditions.

Color adds a distinct and new dimension to pictorial reproduction,

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

5-33

the value of which is hard to weigh in terms of mere black and white definition. In medicine, it is an accepted fact that color television is an invaluable aid in teaching, and four installations have been completed in teaching hospitals. Because of the sense of depth, ease of recognition, and the extra apparent definition furnished by color, black and white television has been almost by-passed in this field.

To a large degree a parallel can be drawn between the requirements in medicine and those in reconnaissance or battle area survey. In both cases, maximum recognition and orientation of objects and areas within the shortest possible time are essential. Color in both cases enhances the illusion of depth and in the case of reconnaissance, the possibility of camouflage detection becomes an important factor through the proper use of the color filters.

The concept of "color" should be expanded to include the addition of a heat detecting signal which could be superimposed on the usual monochrome or color picture. In the direction of a simpler system, two toned pictures should be evaluated for reconnaissance usefulness. And to further conserve bandwidth, it is suggested that useful observational data would result from slow re-examination of the same scene when viewed through specific color filters.

It will probably be possible to relate this proposed project to the evaluation which the Navy is about to make on amphibious landings using an airborne color television chain developed by the Columbia

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

5-34

Broadcasting System.

A smaller phase of this project should be directed to evaluation of stereo applications of television. DuMont has already examined range finding aspects of stereo television for the Signal Corps, but further investigation can be pursued into higher resolution stereo cameras and greater separation angles.

5.5 Summary of Recommendations:

A review of the foregoing sections contains recommendations that five distinct television reconnaissance systems be undertaken on immediate development programs. One of these systems is actually a tactical weapon for use against enemy mortars. In addition, four developments are recommended with the intention of creating new components or techniques which will in time supplement the shortcoming of earlier systems. All of these projects are considered to be feasible within present trends of the art. It is anticipated that with proper encouragement, experimental models for field evaluation could be expected within the particular year indicated.

1. Portable Television System for the Infantry, 1954. Continuous day use, intermittent at night. Infrared model by 1956.
2. Helicopter Television Mortar Locator System, 1954-5. Equally useful for general reconnaissance when illumination is provided.
3. Controllable Missile Television System, 1954. Continuous day reconnaissance and intermittent night use covering near or far enemy terrain.

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

5-35

4. Rocket Reconnaissance System, 1954-5. Expendable rocket camera to obtain single film strip, day or night.

5. Tank Television System, 1954. For armored reconnaissance, primarily by day.

6. Storage Camera Tube Development, 1954. To provide a component optimized for intermittent night viewing and to conserve bandwidth in relaying data.

7. High Resolution Camera Tube Development, 1954. To provide more detailed information from all types of military television systems.

8. Multi-Lens Optical Development, 1954. To enhance the coverage-resolution factor of any television camera.

9. Color Television for Reconnaissance, 1954. A practical study to evaluate the contributions of color.

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

CHAPTER 6

INFRARED

6.1 Introduction:

Infrared techniques and devices have a number of important military applications, among which are: nighttime surveillance, as a communication system over limited distances, and in gas analyzers.

"Seeing" at night by the utilization of infrared radiation can be accomplished both by active and passive techniques. In the active case, the region to be observed is illuminated by an infrared source, and this region is viewed by devices which are sensitive to this radiation. Such infrared systems were actively used during WW-II, and any enemy would also possess them. In this case, as in the applicability of any active physical sensing device known to be in enemy hands, the essential advantage will be held by those with the highest quality and highest sensitivity devices. Consequently the state of the art must be continually improved to maintain a condition of equality and perhaps to attain some measure of advantage.

In passive infrared, utilization is made of the fact that all objects at ground temperature or higher emit radiation in the infrared region. Hence, information can be acquired from the objects being viewed or detected, as they themselves are the sources of the radiation. Moreover, such information can be acquired without necessarily disclosing that such observations are being made. Furthermore, it would be extremely difficult, if not impossible, for the enemy to devise methods to reduce this radiation to intensities which would

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

6-2

escape detection. Because of these features, passive sensitive detecting and viewing devices are an important ultimate goal of a program for the utilization of infrared in a surveillance program.

It should be stressed that infrared methods have limitations as well as capabilities. Their limitations are their relatively short range, perhaps always less than 10 miles, and their dependence on reasonably good weather conditions for efficient transmission, since clouds, rain, fog, haze or smoke definitely limit transmission distances. It does not appear that the full potentialities of infrared for surveillance, within the known limitations, have been fully explored and utilized.

A second and very practical factor has been the unavailability of suitable components. At the present time, this difficulty has been overcome to some extent. Sensitive elements are now available which permit several of the functions in the surveillance program to be carried out by infrared techniques and projects now in the research stage indicate a remarkable potential for night battlefield reconnaissance. By proper selection of applications for infrared and its use in conjunction with complementary techniques, the potential effectiveness of equipment utilizing available components is greatly increased.

6.2 Infrared Techniques:

6.21 Classification. Infrared equipment can be classified in a number of ways. One classification relates to the portion of the spectrum in which the devices operate, and is constituted as follows:

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

Near infrared	0.8 - 1.5 microns
Intermediate infrared	1.5 - 8 microns
Far infrared	8 - 40 microns
Very far infrared	40 - 1000 microns

All devices operating in the near infrared are non-passive. In other words, they require a special infrared source in their operation. Intermediate infrared equipment can be said to be semi-passive: that is, it will respond to objects at a somewhat elevated temperature, such as airplane engines, trucks, factories, tanks, etc. At the present time they do not give useful response to objects whose temperature is in the vicinity of ground temperature. This equipment may also be used with special sources. Far and very far infrared systems are sensitive to the long wave length radiation emitted by all objects at room or higher temperatures and are, therefore, truly passive in their functioning.

A second classification of infrared devices relates to the type of function they perform and divides the field into:

- (a) Imaging Devices.
- (b) Point by Point Detectors.

In all infrared devices; the detection by the sensitive element is made possible by utilizing either the photoemissive, photoconductive or the thermal properties of the material of which the detecting element is made.

6.22 Imaging Devices

6.221 Image Tube (Near Infrared Region). The widest application

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

of infrared at present is for viewing objects which are illuminated with a near infrared illuminator. The scene thus illuminated is in complete visual darkness, and the source itself cannot be seen by the unaided eye. The viewing is done with an infrared image tube combined with an appropriate optical system to form a telescope.

The image tube is an electron tube with an extended cathode, one end of which is sensitized with cesium oxide and silver in such a way that it will emit electrons when infrared radiation falls on it. The electrons are accelerated through an electron optical system which focuses them into an image on a fluorescent viewing screen. In other words, electrons from a given point on the photocathode are converged onto a corresponding point on the fluorescent screen so that any infrared image focused on the photocathode is reproduced in visible light on the viewing screen.

Image tubes have been developed in several types (1P25, 6032, IC16, IC6), which require from 4 to 20 kilovolts over-all voltage for its operation. However, the current requirements are very small indeed, being less than a microampere in normal usage. Therefore, the power to operate it can be readily obtained from a lightweight, rugged battery-vibrator-transformer combination.

The sensitivity of the present day image tube is such that, if an area on the photocathode is illuminated with light from a tungsten light source at normal temperatures, i.e., 2870° K, the brightness of the reproduced area on the viewing screen will be thirty to forty

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

6-5

times the cathode illumination. If an infrared filter of sufficient density so that it can be considered secure for practical military operations is imposed between the source and the image tube, the brightness of the viewing screen will still be three to four times the cathode illumination.

Although several types of image tubes have been developed almost to the point of production, the problems of slumpage and cold emission have not been fully solved. Also, it appears important to develop tubes with very high conversion indices, and also to provide larger apertures. Consequently further development work seems justified on the image tube.

6.222 The Infrared Image Orthicon. The image tubes discussed above are direct viewing and do not by themselves offer the possibility of transmitting an image of the viewed scene to a remote point. The television camera tube, known as the image orthicon, can, however, be modified to serve as a device for obtaining remote pickup of infrared images. Like the image tube, the image orthicon has a photocathode on which the scene under observation is imaged. The photoelectrons from the cathode are refocused into an electron image on a special screen. In the case of the image orthicon, this screen is a storage target which is scanned on the opposite side by an electron beam. The storage target accumulates the information in the image in the form of stored charge over its surface. A low velocity electron beam sweeps over this target in a series of straight parallel lines and removes the

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

6-6

accumulated charge as it passes over each picture element. The difference in charge removed from one picture element and the next causes a variation in the electron current which is returned from the target to a secondary emission multiplier. This fluctuating current, after amplification in the multiplier, constitutes the video signal output of the tube. The video signal can be used by ordinary television techniques to reconstruct the image focused on the cathode of the image orthicon. Normally, the image orthicon is sensitized to respond to visual light only. However, it is possible to sensitize the cathode in exactly the same way as in the image tube so that it will respond to near infrared radiation.

The effective sensitivity of the image orthicon is somewhat lower than that of the image tube. The difference in sensitivity depends greatly upon operating conditions. For detecting signal or marker lights at very low levels, the image orthicon is probably two or three orders of magnitude lower in sensitivity than the image tube combined with a similar optical system and used by an expert. For an extended scene requiring reasonably good picture quality (e.g., such as would be necessary for reconnaissance, driving, etc.), the difference in sensitivity is less than an order of magnitude. With an F/2 objective and the 30 watt source, an infrared orthicon could reproduce a usable picture at 50 to 70 yards, and with a 1 - kilowatt searchlight, the range would probably be 500 yards.

The auxiliary equipment associated with an image orthicon is

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

6-7

much more extensive than that required for an image tube. However, recent advances in television techniques have reduced the weight and bulk of this equipment very greatly. The minimum weight of an infrared camera tube together with the electrical equipment required for its operation and a small ultra-high frequency transmitter would probably be less than 50 pounds, exclusive of the batteries or other power source needed to supply the unit.

6.223 The Brightness Intensifier. While not primarily an infrared device, the brightness intensifier belongs in the class of imaging equipment useful when visual security is required. Intensifiers have been designed to operate as direct viewing devices or to produce a video signal. The former have been developed somewhat further to obtain a usable picture of a scene when the light level is so low that objects cannot be distinguished with the unaided eye. They are passive in the sense that starlight, even in fairly wooded terrain, provides enough illumination to give a reasonably good picture. Since it is known that the largest fraction of the night sky illumination is in the near infrared region (0.6 to 1.2 microns) it may be possible, as the Project Vista Report suggests, to use effectively the intensifier with surfaces sensitive to this spectral region.

The brightness intensifier telescope employs an electronic image converter consisting of cascaded image tube sections arranged to produce an image on the final viewing screen which is many times brighter than the scene before the telescope objective. This attribute alone is not

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

6-8

sufficient to characterize the device, since, for example, a television system consisting of a camera and projection kinescope also has this property, but would not reproduce a usable image at light levels below the threshold. The second condition which must be fulfilled is that the instrument must be capable of extracting all of the information possible from the primary image which is focused on the photocathode of the intensifier tube. The cathode is processed to have the highest possible quantum efficiency (e.g., 10 to 20 percent) and each photoelectron is multiplied by the intensifier stages until there is sufficient charge to produce a visible scintillation. Any further intensification will not increase the information contained in the image.

Although this class of equipment will reproduce images at very low scene illumination, its application as a direct viewing device is limited. The human eye, which is an extremely sensitive optical device makes as efficient use of light photons as does the instrument in question. Therefore, an intensifier can only surpass the eye in sensitivity by virtue of the fact that it may employ an objective which is much larger in diameter than the pupil of the eye. Night glasses with large objectives can increase the light gathering power of the eye but only at the expense of angle of vision. The intensifier, on the other hand, gives the added information without this sacrifice.

An intensifier arranged to give a video signal output should permit television pickup with scene brightness one to two orders of magnitude

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

lower than is required for an ordinary image orthicon. This may be quite important for remote surveillance, night aerial reconnaissance, etc.

6.224 Intermediate Infrared Imaging. (1956-60). In addition to their application in point by point response detectors, photoconductors, to be discussed later, may be used for infrared imaging. For this application, the photoconductor takes the form of a thin, very high resistance layer, deposited on a conducting film on a transparent supporting layer. The free surface of the photoconductor is bombarded by low velocity electrons, which determine its surface potential, while the backing layer is made slightly positive or, less frequently, negative with respect to the free surface. The point by point conductivity of the photoconductor, which in turn is determined by the distribution of infrared radiation falling on it, governs the fraction of electrons which are returned from its surface under equilibrium conditions. This form of photoconductive target may be used for direct viewing in a mirror image tube or a velocity selector image tube. Such Heat Image Tubes are being developed at RCA under Corps of Engineers contract. It may also be used to obtain a video signal output in a beam scanning tube. Both types of devices are still in research stage, but the latter is somewhat further advanced.

Where such targets are used in beam scanning pickup tubes, the mechanism of operation is as follows. As the scanning beam passes over the surface of the target, each element under the beam is brought to

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

an equilibrium potential. As the beam leaves an element, the element will start to charge positive. The rate of charge will depend upon the illumination of the target in its vicinity. This charging continues while the beam is scanning the rest of the target. When the beam returns to the element in question, it again drives it to equilibrium. When an element is in complete darkness, its change in potential will be very small, while elements in the brighter portions of an infrared image may change their potential considerably in a frame time. The action of the beam in driving elements to equilibrium is simply that electrons are retained by the elements until it has charged to a sufficiently negative potential so that beam electrons can no longer reach it but return to a secondary emission multiplier system in the back part of the tube. Fewer electrons are returned to this multiplier from an element which has been charged positive by intense radiation than from an element in darkness. This difference in returned current gives rise to the video signal output.

It should be pointed out that every elemental area of the target is making use of the incident infrared photons all of the time and not merely during the time the beam is on a particular area. This storage feature gives an enormous gain in sensitivity over any point by point method of forming an infrared image. It is probable that eventually storage targets in beam scanning tubes will be very widely used in the infrared field not only for imaging but for the solution of such problems as detection, fire control, missile guidance, etc.

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

6-11

At present, intermediate infrared sensitive beam scanning pickup tubes have been made in the laboratory based on modified lead sulfide photoconductors. Such targets have exhibited sufficient sensitivity to form images of objects at 200° C or somewhat lower and will give a threshold signal from objects only slightly above the temperature of boiling water. The long wavelength cutoff of such targets is 2.0 to 2.1 microns. This type of imaging device is being tested as a detector of objects such as airplane engines, jet exhausts, etc., and in active imaging systems where the illuminator emits radiation in the 1.5 to 2 micron region, thus being relatively secure against detection by the near infrared imaging devices such as the Snooperscope. While it is doubtful whether the present sensitivity is adequate for practical application, nevertheless there is considerable reason for optimism for this type of device, and practical equipment may be available by the 1956-1960 period.

Mirror image tubes based on targets similar to those in beam scanning tubes are being investigated in laboratories in this country. At present their sensitivities are still considerably lower than those of beam scanning devices but this fact is probably not an inherent property of this class of device. Mirror image tubes have in their favor that the auxiliary equipment required is much less expensive than that for any device which produces a video signal output.

6.225 Far Infrared Imaging.

(a) Photoconductive imaging (1956-1960). Passive infrared

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

6-12

imaging using tubes involving the same beam scanning principles outlined above but employing low-temperature impurity-photoconductors is one of the most promising lines of development in the infrared field. The high quantum efficiency and high sensitivity of impurity photoconductors imply that, in terms of the number of photons available for imaging, they should be equally as effective as, for example, as photoconductive pickup tubes, such as the vidicon, are in the visible. A simple estimate shows that a surface at room temperature emits ten times as many photons in the 8-1/2 to 12 micron region as there are visible photons from a surface at 1000° C. Therefore, it is evident that the infrared luminosity of room temperature objects is amply adequate for imaging. Little is known at present about the contrast which results from variation in emissivity, reflectivity and local temperature variations. Some guide to this has been obtained from images formed with the evaporograph and from the results of thermal mapping where bolometers are used.

Passive imaging systems based on impurity photoconductors will necessarily have to be cooled to at least liquid hydrogen temperature and, possibly, close to liquid helium temperatures. It is felt, however, that on a long term basis, this is not a serious drawback and that by the time the imaging devices are ready for practical application, the cryogenic problem may be completely solved.

(b) The Evaporograph. (1954-1956). This device differs from all the viewing methods described previously in that it operates on

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

6-13

the differential evaporation or condensation of an oil film on a surface due to the heat radiation impinging upon the surface rather than upon the photoemissive or photoconductive properties.

The important part of the evaporograph cell is the membrane in the center which divides the cell into two parts. The membrane is blackened on one side, and oil, contained in the right side of cell, is deposited on the other side of film. The image, to be viewed, is focused on the black side by a suitable optical arrangement. Due to the different heat content of various parts of the image, there is a differential condensation of oil on the surface. If this film is properly illuminated, a picture can be observed with the naked eye or it can be photographed or televised. The picture is formed by interference phenomena and appears in color, the color of the image of an object being dependent upon its temperature.

This viewing device is completely passive. It forms a picture by the radiation which is emitted from the objects at which it is looking. Since all objects emit radiation, it can be used without the necessity of any external illumination.

The action of the evaporograph is exactly analagous to that of a camera. In ordinary photography, the most distinct objects are those which put the most light on the photographic plate. In evaporography the most distinct objects, i.e., the hottest ones, are those which put most energy on the film. Thus the evaporograph sees apparent temperature differences.

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

6-14

The existing evaporograph model can see a temperature difference of approximately $1/2^{\circ}$ C. The image of the object in the evaporograph is not formed instantaneously, the length of time which it takes this image to form depending on the temperature of the objects. An object with a high temperature will be imaged almost instantaneously while an object with a low temperature will require some time to be imaged. This can be better phrased by saying that to see a $1/2^{\circ}$ C temperature difference between two objects which are at 1000° C requires $1/1000$ sec. or so. To see $1/2^{\circ}$ C difference between two objects which are at room temperature will take perhaps 40 seconds. The temperatures which the evaporograph sees are not the actual temperatures of the objects but the apparent temperatures in which the color or emissivity of the objects are involved. Accordingly, an enormous amount of detail can be seen in the evaporograph even though one might think at first that all the targets were at the same temperature.

6.226. Passive Photo-Emission Viewers (Contract AF 33-038-22803). This type of device in the early research stage, and it is too early to judge if it will have any practical application as an infrared imaging device. It operates on the following principle: A heat image is focused on the photocathode of the tube. The cathode is scanned by a visible light spot. Due to different temperatures of the photocathode, effected by the infrared image, there is a variation in the number of photoelectrons emitted from the various regions which modifies the signal transmitted to a cathode ray viewing tube.

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

6-15

6.23 Point by Point Response Detectors.

6.231 General Considerations. The point by point response detectors which show promise for battlefield surveillance are primarily those of the bolometric and photo conductive types.¹ Devices utilizing point by point detectors obtain varied signals from the sensitive element, depending on the infrared radiation incident on the element, and when these elements are used with appropriate optical and scanning arrangements these signals can be transmitted to an electronic system which synthesizes a picture.

The physical principles involved in the operation of these detectors is as follows: In the bolometric type, groups of photons are absorbed and the resulting temperature rise changes the electrical resistance of the receiving element. In the photoconductive type with the absorption of photons, loosely-bound electrons are internally "freed" and hence, due to the increase in the number of electrons available, there is a change in the resistance of the receiving element.

Two types of bolometers are now commercially available, the low resistance metal strip type and the high resistance thermistor type. Super-conducting bolometers are still in the laboratory stage.

-
1. It seems quite probable that point by point detection by radar techniques, of the microwave radiation emitted by all objects will be developed in the near future. Such a technique of point to point detection is discussed in Section 4.28.

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

6-16

Of the photoconductive type, lead sulfide cells are available commercially while lead selenide and lead telluride cells are now available on an individual order basis and may soon be available commercially. Recently it has been shown that certain semi-conductors, mainly germanium and silicon, show remarkable promise as photoconductors in the far infrared region when cooled to very low temperatures (25° K or less).

The capabilities of these types as detectors are generally described in terms of the following three characteristics:

1. Spectral sensitivity
2. Threshold of sensitivity or noise equivalent power
3. The frequency characteristic or time constant

By spectral sensitivity is meant the spectral region in which the cell shows considerable photoconductivity. This characteristic of the cell takes on special importance when it is realized that there are limited spectral regions in which infrared radiation can be transmitted without absorption. These regions, often referred to as atmospheric windows, are at 2.0-2.5 microns, 3.5-4.7 microns, and 8-12 microns.

6.232 Threshold of Sensitivity or Noise Equivalent Power. Every cell has a noise level of its own which produces random signals in the detecting device. The radiation to be detected, therefore, must produce signals which exceed the noise signals, if any positive detection is to be accomplished. As a measure of the threshold of sensitivity a term has been adopted, called the Noise Equivalent Power, which gives

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

6-17

the power of the radiation (usually expressed in watts) for which the response of the cell is equal to the random noise of the cell.

Two additional factors should be mentioned at this time since they are related to the threshold of sensitivity or Noise Equivalent Power. The first has to do with the area of the sensitive layer of the cell. As the area of the cell is decreased, the fainter will be the radiation which can be detected by the area, (i.e. the Noise Equivalent Power decreases).

The other factor has to do with the actual operation of the detector in military equipment. The noise level of the detecting device under operating conditions may exceed many fold the noise level of the cell. Hence, the noise equivalent power of the cell may not be the limiting factor in determining its capability as a detector of radiation in actual operation.

6.233 Frequency Characteristics or Time Constant of the Cell.

The ability of a cell to respond rapidly to an increase or decrease in the radiation it encounters is of utmost importance in determining its value as a detector, especially in scanning devices. This characteristic is expressed by the time constant, the time required for the signal output of the cell to decay to one over E or 37% of its peak output.

The capability of the various detector types in terms of the characteristics mentioned above are summarized in Table I. The data for this table were taken from the Project Metcalf Report.

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

TABLE I
SUMMARY OF CHARACTERISTICS OF POINT TO POINT DETECTORS

Type	Spectral Region of : : good sensitivity : : in : : microns	Noise Equivalent* : : Power in watts/cm ²	Area of : : sensitive : : surface : : in sq. cm.	Time constant : : in seconds
Bolometers				
Metal type (Room temperature)	1-13	7.5×10^{-7}	.0024	1.4×10^{-3}
Thermistor type (Room temperature)	1-13	1.0×10^{-7}	.0025	1.9×10^{-3}
Super conducting (at liquid helium temperature)	1-13	3.3×10^{-12} (est)	.01	3.0×10^{-3} (est)
Photoconductors				
Lead Sulfide (Room temperature) (1)	.8 - 2.5	5.7×10^{-7} - 3.3×10^{-9}	.02-.36	$1. \times 10^{-3}$ - 1.0×10^{-5}
Lead Selenide (Room temperature)	1.8 - 3.2	$5. \times 10^{-8}$ - 3.2×10^{-8}	.12 to 0.45	2×10^{-5} - 5×10^{-6}
Lead Telluride (Liquid air temperature)	2. - 4.2	5.5×10^{-9} to ?	.025	2.5×10^{-5} - (?)
Germanium (Liquid helium temperature)	2 - 14 - 100 ?	3×10^{-9}	.20	10^{-3}
Silicon (Liquid helium temperature)	2 - 25	1.7×10^{-8}	.38	5×10^{-5}

*The Noise Equivalent Power is based on the response to radiation from a black body target at 500°K and for a calculated amplifier bandwidth of 1 cycle per second. The chopping frequency was 90 cycles per second except for the following (Metal type bolometer - 120, Thermistor bolometer - 28, Germanium - 25, and Silicon - 1000)

(1) Cooled lead sulfide cells show good sensitivity to about 3 microns. The Noise Equivalent Power decreases by a factor of 10-50 times and the time constant increases by a factor of 2-4 times over the value at room temperature.

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

It should be noted that each type of point by point detector now available has certain advantages and disadvantages.

With bolometer type detectors radiation is detected in the 1 to 13 micron region and hence they are able to detect radiation transmitted through all the "atmospheric window" regions. Also, since all objects radiate according to the well known radiation laws of Planck and Wien, bolometers are sensitive in the region where the radiation is a maximum from black bodies whose apparent or effective temperature is that of ordinary ground temperature or higher. The disadvantage of the bolometer is that it is rather slow in its response (the time constant is ordinarily in the milli-second range) and, therefore, cannot be utilized with fast scanning systems needed to give high resolution or detail.

The photoconductive cells, on the other hand, are fast (time constant in microsecond range) and thus can be utilized in fast scanning systems. Also, they are much more sensitive than bolometers in their detecting power. Their disadvantage, however, is that the cells now available respond only to wave lengths shorter than five microns and hence can utilize the radiation transmitted only through the 2 - 2.5 and 3.5 - 4.7 atmospheric windows. Since only objects with effective temperatures of 50° C or more radiate appreciable energy in this region, the currently available photoconducting detectors are efficient only against hot targets. On the other hand, since objects at ground temperature do radiate some energy in this wave length region and the photo-

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

6-20

conducting cells are rather sensitive, there is a possibility that in the future lead selenide and lead telluride cells will serve as satisfactory detectors for such temperature objects. If such detection is possible, these cells should be able to detect rather small effective temperature differences since such a difference results in a large percentage change in the radiation in this region. The short time constants of these cells should then allow rather improved resolution in thermal maps.

6.234 Passive Microwave Detection. Point by point detection of the thermal radiation of ground objects in the microwave region (3-18mm) by radar techniques is discussed in considerable detail in the Beacon Hill Report. As pointed out in that report, if such a detection system is possible, it should have considerable merit, particularly due to the all weather capability of transmission of radiation of these wave lengths. Pictures obtained by this technique should be quite different from those obtained by infrared techniques and correlation of such pictures with those taken in the various regions of the infrared spectrum should be of value.

The technique is one of radar, and is considered in Section 4.28. The Air Force has three contracts now in effect on this problem, one each at Sperry Gyroscope Company, Air Force Cambridge Research Center, and at Project Lincoln.

6.3 Infrared and the Battlefield Surveillance Problem:

This section will discuss how the various techniques described in

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

6-21

Section 6.2 can be utilized in fulfilling the various functions of a surveillance program. It should be stressed again that infrared has limitations as well as possibilities and that infrared techniques should be considered only as one of the avenues for obtaining the required intelligence data. Whenever infrared can complement or be complemented by another technique, such fusion of functions should be encouraged.

For purposes of discussion, the applications of infrared techniques in obtaining information in regions at various distances in front of the battleline, such as ranges from 0 to 300 yards, 300 to 3000 yards, and 0 to 200 miles, will be considered. These ranges are of concern to various groups of personnel and hence the discussion of the applications of the techniques can better be described when associated with the personnel who would use them.

6.31 Range: 0 to 300 yards. In this range we are concerned with the foot soldier and personnel in front line vehicles such as tanks and jeeps. The requirement is to recognize and identify personnel and vehicles.

6.311 Near Infrared Viewing Devices Utilizing the Image Tube (1952-1954). At the present time, only devices of the active type are available for these personnel. These use an infrared source to illuminate the area and the viewing is done with an infrared Image Tube combined with an appropriate optical system to form a telescope. Among the devices of this type are the Sniperscope (Sniperscope, IR,

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

6-22

Set #1-20KV), Image Metascope (Monocular IR), Viewing Telescope (AN/SAR-4) for ground personnel and the driver's and commander's binoculars and the gunner's monocular (all Leaflet II) for the vehicle personnel.

In the Sniperscope the source is attached to the viewing tube which is fitted to the gun. With a 30 watt filtered tungsten source, personnel can be recognized with the sniperscope and image metascope at ranges up to 125-150 yards; with a 100 watt lamp, at ranges up to 350 yards.

In the operation of vehicles, with 85 watt filtered headlights the driver's binoculars allow seeing to 75 yards in a complete blackout. With a 1000 watt, 18 inch filtered searchlight on a tank, the tank commander and gunner can recognize tanks out to 400 yards. With the viewing telescope and a 60 inch searchlight (mounted on truck), personnel can be detected at ranges up to 600 yards and tanks to 2000 yards.

There are two principal drawbacks to these equipments. First, they use active infrared sources which can readily be detected and used as targets by the enemy, and second, the power supply required is heavy, bulky and requires frequent servicing.

6.312 The Evaporograph (1954-1956). For the foot soldier, the evaporograph shows great promise as a device which will permit him to see at night without the use of an auxiliary source. The device will perhaps weigh not more than two or three pounds and can be hand held to serve as a snooperscope or fitted to a gun to operate as a sniperscope.

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

6-23

Contrary to the often raised criticism, it is not fragile and should readily stand up under field use. Since the evaporograph is completely passive, it cannot be detected by the enemy. The user will see the landscape brightly illuminated and looking not too different from the way it appears in broad daylight. For the crew in tanks and jeeps it might also serve the purpose for which the drivers and commanders binoculars and gunners monocular were designed.

The evaporograph should be available in the period 1954-56 if its development is strongly supported. The needed developments are: (1) to build a sealed unit and (2) to improve the speed of picture formation.

6.313 Brightness Intensifier (1954-1956). This device should be available in the 1954-1956 period, and if it can be built into a light and compact unit, it may be of considerable use to the foot soldier. It has the advantage of a passive instrument as it would use moonlight or starlight as a source for seeing in the visible. If near infrared intensifiers are developed it could use the natural infrared night sky illumination as a source. For vehicles the problem of compactness and weight will be less critical.

6.314 Penrod and Scanrod. A number of units have been or are being developed for use by the front line soldiers for specialized tasks such as protection of areas or lines of defense, target detectors, etc. One of these is Penrod.

This device, developed by the Army Corps of Engineers is designed

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

6-24

for perimetral safeguard against intrusion. It utilizes a thermistor bolometer as the detecting element and is thus a passive detector. A change in signal is produced whenever a warm object such as personnel or vehicles enters the field of view. This signal may be transmitted to any desired point by wire, radio, or infrared communication to record the intrusion.

A modification, known as Scanrod, includes a recording (paper) device which indicates target detection.

6.315 AN/PAS-2. This unit is under development by the Signal Corps and serves a similar purpose to Penrod for perimetral safeguard. It may be used at night in a network for crossfire control.

AN/PAS-2 consists of three basic units: the transceiver assembly, the triple mirror and the remote control unit. The principle of operation is simple. A highly collimated beam of light, modulated by a reed vibrator unit and secured against visual and snooperscope detection by means of an infrared filter, travels in a straight line to the triple mirror which is placed at a maximum distance of 400 yards from the transceiver assembly. The triple mirror, because of its unique property of reflecting light in the direction parallel to itself, returns part of the light to a collector mirror in the transceiver assembly which, in turn, focuses it upon a photoconductive lead sulfide detector. Also upon the detector falls modulated light, known as the "failsafe" light, 180° out of phase with the beam being returned from the mirror. This light, which is 180° out of phase comes from the same lamp, is

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

6-25

modulated by the same reed, and is imaged upon the same photocell. This light is adjusted in amplitude to almost equal in amplitude the direct light (light along the path being protected). The resultant signal from the photocell is small; any change in either the direct or "failsafe" light will give a large change of signal which, upon amplification, operates aural and visual indicators for alarm. The sense of the change in level of the system determines whether it is an indication of alarm or system failure. A relay is provided which can carry a heavy current for automatic actuation of a machine gun or other device. In addition, provision is made for remote control operation of the system by a standard field wire pair connection.

6.316 Passive Sighting Devices. Two units are being developed by the Signal Corps, as well as several by the Corps of Engineers.

(a) Model 1. (M1). This is a unit which can be hand held to the eye and will give visual (and if desired, aural) presentation. It consists of a lead sulfide detector and a small motor which turns a scanning mirror in front of the cell and also a slotted disk in front of eyepiece. When the field of view contains a hot object, as a tank or vehicle, the signal from the cell illuminates a neon lamp inside the unit. The light from the lamp reaches the observer's eye through the slot and since the latter is synchronized with the scanner, the direction to the object can be determined.

(b) Model 2. (M2). This model, designed by Signal Corps, is under development by the Eastman Kodak Co. It will utilize either

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

6-26

a mosaic lead sulfide cell or a thermistor bolometer mosaic. This unit will provide an image type of presentation and can be hand held. The Corps of Engineers has under development contract a passive sighting telescope utilizing a thermistor bolometer array (3 elements). Also under development are passive aiming sights using lead sulfide detectors in arrays.

6.317 Integrated Radar - Infrared Target Identification Set.

An integrated unit, consisting of a radar unit AN/PSS1, which is an X band doppler-radar set, an infrared pulsed rangefinder, near infrared viewer and passive received M-2, is contemplated by the Signal Corps. This unit is also discussed in Section 4.31.

Another kit of lightweight devices has been proposed. It consists of a AN/PSS-1 radar set, near infrared viewer AN/AAR-1, the passive sight M2, passive intrusion detector utilizing a bolometer, and a search scanner utilizing both a photoconductive cell and a bolometer.

The purpose of the proposed kit is to provide a forward element with sufficient equipment to perform a variety of detection and surveillance functions. The individual portions of the kit can be either utilized separately or in an integrated fashion so that improvement in operation, maintenance and logistics can be achieved. The efficient use of these kits will depend greatly on the training and ingenuity of the personnel assigned to their use.

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

6-27

6.318 Warning Devices to Foot-Soldier. If the soldier has a snooperscope, or an image metascope* he can detect an infrared source if it is in the field of view of the instrument. He can thus be warned if he is being illuminated with infrared.

Two other warning devices of this type are available or under development. A phosphor type metascope, developed by the Corps of Engineers is available. The second device, being developed by the Signal Corps, is a helmet mounted warning receiver utilizing a caesium cell. It is an automatic device which lights a neon bulb when the cell is activated. By flipping a switch a direction cell is connected into circuit and by turning of the head, the soldier can determine the direction of the source of illumination.

6.319 Infrared Image Orthicon (1954-1956). When the infrared image orthicon tube becomes available, it may well be utilized for near infrared imaging in the range of 0 to 300 yard region. It can be set up in remote unattended stations overlooking strategic areas and the information transmitted to a central point by wire, radio, or infrared communication. In a tank or armored vehicle, it could be placed in a relatively exposed position and the image could be reconstructed at a protected position in the interior. In fact, since a complete orthicon unit would not represent a large investment, it probably would be

*An image metascope with a built-in infrared source can be used for the purpose of map reading.

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

6-28

incorporated in robot vehicles where its eventual destruction is nearly a certainty, in order to obtain vital information.

6.32 Range: 300 to 3,000 yards. For this range it is assumed that observation posts have been located at positions allowing line of sight reconnaissance. Of particular importance are facilities for long range detection of targets in enemy territory.

6.321 Flash Ranging.

(a) AN/TVS-1. This flash ranging set is a photographic unit for gun location and as such belongs in a discussion of photographic rather than infrared devices.

(b) AN/GAS-1. This unit utilizes a lead sulfide cell and is effective against guns utilizing flashless powder. Investigations of the energy distribution of such gun flashes show that the optimum spectral region for detection lies in the 1 to 5 micron region. Field tests with this unit have shown that these units have detected suppressed flashes under conditions where visual and photographic methods gave no detection.

6.322 Identification Systems. At the present time the M-2 beacon, developed by the Army Corps of Engineers is an equipment available for night-time operation for marking and identification. It consists essentially of a filtered tungsten source utilizing a coded shutter which can operate in either the visible or near infrared.

A system which permits operation both in day-light and at night is under development by the Signal Corps. The system employs coded

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

6-29

interrogation by either radio or radar and an infrared reply from radar-infrared responders. The infrared reply is detected by a photocell and its signal converted to a visible signal superposed on the visual field of view of the observer, thereby giving him the illusion that the target is replying with visual signals.

While the kit of lightweight devices, described in Section 6.317 is applicable for use from observation posts, certain replacements are contemplated. A pulsed reconnaissance system is being developed by the Capehart-Farnsworth Corporation for Signal Corps. The system will employ momentary illumination of the target with single pulses or pulse trains. The detection of the reflections will be accomplished with an image storage tube. It is hoped that greater ranges of illumination will be obtained with relatively small power in the source and at the same time improved security of the source.

6.323 Possible Future Developments. Pending the development of viewing systems such as the intermediate infrared and far infrared imaging tubes (photoconducting or evaporo-graph), it may be possible to apply the point by point detectors in scanning systems which will give synthesized panoramas of night scenes which can be observed at the spot or transmitted to a distant point. The resolution should be better with lead selenide or lead telluride cells than with bolometers, mainly because of the speed of response of these cells.

When the passive imaging tubes become available, night passive imaging leading to photographs roughly similar to present day television

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

6-30

pictures should be possible. Since it is possible to utilize these imaging tubes for presentation of the panorama as it is emitted in various spectral regions, considerable information should be available to a trained observer by simultaneous presentations of the scene as it appears in these various spectral regions.

6.324 Surveying Systems. Frequently it is desirable to carry out surveying in the front line area under the cover of darkness for purposes of establishing base lines, coordinate systems, etc. A variety of infrared surveying devices have been developed by the Army Corps of Engineers for this purpose. These include an infrared transit, a ranging system, etc. Other equipment of this nature can be developed if demand exists.

While it is felt that mention should be made of this technique here, the actual process of surveying is not deemed to fall under the heading of battlefield surveillance.

6.33 Range: 0-200 miles. In this range information must be obtained from the air by use of piloted aircraft, drones, balloons or perhaps missiles.

For reconnaissance, information is needed regarding the nature of the terrain, - roads, rivers, bridges, etc. and for the location of enemy personnel vehicles, artillery, installations, etc.

At the present time, only two systems are available, the Thermal Reconnaissance Device and the Infrared Detecting Sets - AN/AAS-1 and AN/AAS-2.

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

6-31

6.331 Thermal Reconnaissance Device (TRD). This unit was developed by Servo Corporation of America for WADC and is a thermal mapping device. It uses two thermistor bolometer detectors, each covering a $0.5^{\circ} \times 0.5^{\circ}$ field of view, butted together giving a resolution of $0.5^{\circ} \times 1.0^{\circ}$. The time constant of the bolometer is in the order of 2. milliseconds. The scanning is accomplished by three spherical mirrors spinning circumferentially about the sensitive elements, with the forward motion of the aircraft providing the forward motion of the line scan. The presentation of the intensity of the signal is made on a cathode ray tube. Photographing is possible by moving the film over a slit aperture in front of the cathode ray tube. The speed of the film movement is synchronized with the forward movement of the airplane and the rotation of the mirrors.

The unit has been flown by Servo Corporation over various areas including Manhattan Island, various airports, barrack areas and the country side. Pictures have been taken in day time and at night. Elimination of day light and the near infrared from the record were effectual through the use of a silver-sulfide filter which cut out the radiation shorter than 4.3 microns. This filter also eliminated the effects of street lights, etc. at night. It should be added that no pin point targets, such as tanks, were detected from the air with this system, although they were recorded from the ground. Improvements may be possible to allow the detection of such pin point targets.

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

6-32

6.332 Infrared Detector Sets AN/AAS-1 (XA-2) and AN/AAS-1 (XA-3). These sets are of the German Kiel type, modified so as to give better sensitivity and are used for the location of targets whose temperature is in the range of 100°C or more above ground temperature. At the present time an Armour Research Foundation cooled lead sulfide cell having a sensitive area of 3 x 3 mm is the detecting element. The scan pattern is hypocycloidal with 17 complete loops executed in one second to cover a field of view 20°. The incremental field is 1.2 degrees. The resolution is calculated to be 0.2 degrees at the center where 17 pieces of information are received per second and at the periphery of the scanned field, where only one piece of information is received per second, the limit of resolution is that of the incremental field, namely 1.2 degrees. Presentation of the information to the pilot and observer is made on two 3 inch cathode ray tubes.

Test flights with the AN/AAS-1(XA-2), using a cell with an effective cutoff at 2.9 microns (the cut-off is the spectral region where the sensitivity is down to 50% of its peak), have detected M-46 tanks at slant ranges to 3 miles, M-4 tanks to between 1 and 2 miles, and the well shielded Russian T-4 tank at 1/2 to 3/4 miles. Using a cooled cell with cutoff at 3.1 microns, tests showed improvement in detection of M-4 tanks but no range data were acquired. Attempts to detect groups of personnel have been made but no positive indication of personnel could be established; the noise level of the equipment seemed to increase, indicating that with this cell the detection of

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

6-33

personnel was near the threshold of accomplishment.

With the AN/AAS-1(XA-3) instrument using an inferior lead sulfide cell, the Russian T-34 tank has been detected at one mile, locomotives have been detected to 5 miles and trucks (2-1/2 ton) out to 3.5 miles.

Two AN/AAS-1(XA-3) units are now being used in Korea and have been successful in night operations to detect radar sites, and vehicles. In fact, the units have been successfully used as night sights in bombing missions.

A further improved model, AN/AAS-2 is under development at RCA and it is expected that field tests with this unit will be made in 1953.

Since the sensitivity of lead selenide and lead telluride cells extend farther into the long wave length region than lead sulfide, they might be better detectors in the AN/AAS type instruments by a factor of 5 to 8 times. The Air Force is planning to make flight tests with a lead telluride cell (cut-off at 5.2 microns) early in 1953. This cell will have to be liquid air cooled but this difficulty does not appear to be insurmountable.

6.333 Developments 1954-56 period. In the near future, 1954-56, one can expect that improved sets of the AN/AAS type utilizing lead selenide or lead telluride cells will give greater range against tanks and vehicles and might possibly detect personnel. It is highly probable that scanning devices more suitable for air to ground reconnaissance will be devised. It may be that sets of the TRD type will utilize these cells, if it can be established that ground temperature objects can be

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

6-34

successfully detected.

Other techniques should also become available for air to ground reconnaissance during this period. The Evaporograph when supplied with adequate optics can be utilized as well from air to ground as from ground to ground. It will be possible to utilize the evaporograph either with a scanning system or in conjunction with a television camera for transmitting the evaporograph picture to a distant station. The high resolution of these pictures should reveal considerable data.

It is expected that the Brightness Intensifier will also be available for night photography and here too the pictures could be transmitted to a distant station by video techniques.

6.334 Developments 1956-60 Period. In the more distant future, 1956-60, the Intermediate Infrared and the Far Infrared Viewing devices should be available. They too have the possibility of being used in unattended sets in aircraft, drones and balloons and can send their signals to distant receiving stations. The correlation of pictures taken in two or more spectral regions should yield considerable data since objects at different effective temperatures may record differently in various spectral regions. Microwave thermal radar should furnish a still different picture.

6.335 Navigational Aids. At the present time the TRD maps should enable an interpreter to identify certain well outlined landmarks for location purposes. If markers made up of highly reflecting powders and spread over a considerable area (they could be fired or

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

6-35

dropped as a shell which burst or exploded on landing), this highly reflecting surface would have a temperature of the night sky and hence be detectable with the bolometer type mapper because of an effective temperature radically different from that of ground.

If markers with a temperature of 100°C above ground and a radiating surface area of at least 2 square feet toward the air were laid down, they should be detectable with sets of the AN/AAS type. The present method of scanning, however, may not be practical for the location of these markers.

If either of these units were utilized in location of markers, it seems that it will also be desirable to know the position of the plane. This could be obtained by radar methods or using infrared tracking systems.

In the future when the evaporograph and the intermediate infrared and far infrared systems are available, navigation methods may be considerably simplified. If pictures of good resolution can be obtained, methods of aerial photogrammetry similar to those used today in ordinary aerial photography which do not require the knowledge of aircraft position may be applicable.

6.4 Infrared Communication Systems:

Infrared communication systems are subject to malfunction under adverse weather conditions. Hence, their use is limited to specific operational problems, such as short range directional communications, covert activities, river crossings, amphibious operations and air-to-

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

6-36

ground problems involving intervisibility between stations.

Signalling by means of infrared has an important application as a frontline demarcation and IFF system. A system, currently under development, utilizes radar or radio for interrogation and infrared for reply. This system has a clear weather day and night range of six miles.

The two most successful equipments presently available for two-way voice communications at night over invisible light beams, are known as AN/PAC-1 (type W) and AN/SAC-4 (type E). Both equipments are developments of the United States Navy. The AN/PAC-1 consists of a 12-lb. hand-held transceiver and an 8 to 15-lb. sling-carried battery pack. Two equipments operated as "Handie Talkies" form a communications link having a line-of-sight range of 2 to 4 miles in average clear weather. When being used, the operator holds the instrument to the side of his head with the right eye directly in line with the eyepiece of a small infrared telescope, and aims the 4 to 10 degree beam in the direction of the distant operator. Field tests of AN/PAC-1 equipment will determine its suitability for Army use. An important requirement is operation both by day and night and a decrease of weight and size of the present equipment.

The AN/SAC-4 equipment has a total weight of about 170 pounds. Two equipments form communications link capable of transmitting telephone, teletype, or facsimile signals with an average clear weather line-of-sight range at night of 5 to 9 miles. Thirty-five of these

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

6-37

equipments were installed on ships several years ago, and have given satisfactory ship-to-ship service.

Improvements are now in progress at both the source and receiver which may increase the use of infrared in communications. At the source end, solid crystals are being developed as light valves or shutters, which can thus modulate a steady light source. The crystals change birefringence when voltage is applied across the proper axis. Research seems to indicate that the change is essentially inertialess. In other words, it follows the applied field at all frequencies. At the present time the modulation has been carried to a frequency of 14 megacycles. The next experiments will attempt to push this to 100 megacycles.

The possibilities of such broad band communication are enormous. Present crystals operate in the infrared to about 1.6 microns. Receivers, however, will not operate with the same degree of inertia as the shutter in this wavelength region. Accordingly, the practical infrared limit for high frequency operation is probably around 1.2 microns. Several years of research will be necessary before such a wide band communication system would be at all available for field use.

As receivers, infrared photomultiplier tubes and germanium phototransistors are being developed. Infrared photomultiplier tubes using a photocathode sensitized with silver and caesium respond to radiations out to 1.1 and 1.2 microns. These cells are now in pilot production and can be manufactured in large quantities within the next

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

6-38

two years, if requirements warrant it. Since this type of detector is the most sensitive known, it might have wide usage for signaling, as well as for communication.

The germanium phototransistor shows promise as a fast receiver operating beyond 1.2 microns, which is the long wave limit of the photomultiplier. There is hope that the phototransistors may be able to use the 1.5 - 1.8 atmospheric window for signaling and communications. At the present time these phototransistors have a time constant in the order of a few microseconds and only a point contact sensitivity. Research is in progress to explore the possibility of producing phototransistors of a faster response and larger area.

6.5 Infrared Gas Analysers:

The use of infrared radiations makes possible the detection of minute quantities of substantially all the gases with which the military is concerned. Those small quantities of a particular gas can be detected, with very few exceptions, independently of the gas mixture in which they are found. Most military applications would apply infrared radiations to the problem of detecting a very small trace impurity in the atmosphere. Equipments are currently available which will detect carbon monoxide, for example, at about one part in a million and developmental programs are under way which should move this figure in the direction of higher sensitivity by 10 or 100 times. Many gases can be detected in smaller concentrations than carbon monoxide. These determinations are made quickly; that is, in a few seconds.

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

6-39

Infrared detection of gases makes use of the characteristic absorption that nearly all gases have for infrared radiations. A particular gas can be monitored because each gas absorbs wavelengths which are different. A gas analyzer is, therefore, usually composed of a source for the infrared radiations, a region in which these radiations pass through the gas to be analyzed, elements which sort out the desired wavelength regions, and an infrared heat detector. Natural sources may be used so a source unit might not be part of the equipment.

Infrared gas detection may be used as a warning device against lethal concentrations of poisonous gases, to get information of the presence of military units which emit characteristic gases, and to assist other measurements for predicting weather.

The use of infrared gas detection to sense the presence of troop concentrations or vehicles is relatively little explored. Submarines, tanks, trucks, and even campfires add carbon dioxide and carbon monoxide to the atmosphere in quantities which might be detected downwind a useful distance. Equipments designed for this purpose might well make use of a distant infrared source possibly many miles away, so that changes in gas concentration anywhere along the line between this source and the detecting equipment can be noted. At sea a surfaced submarine leaves a trail of combustion products behind. In this subject man is attempting to make use of devices long the most powerful tools of the stag and the hound.

Since water vapor is one of the strongest of infrared absorbing

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

gases, its concentration in the atmosphere may be easily measured by infrared means. The information thus placed in the hands of the meteorologist without cumbersome high altitude sampling techniques is one of the important sources of information useful in predicting weather.

The future usefulness of the gaseous absorption bands in the infrared depends upon techniques unexplored at the present time. Thus, it is not possible to do more now than point in the directions that it will go. Much progress needs to be made in the techniques of making these measurements, but with the recent development of new types of infrared heat detectors and infrared filters there are many applications which require only the design of the specific equipment.

6.6 Conclusions and Recommendations:

6.61 Conclusions. Infrared sensitive elements lend themselves to use in a great variety of devices capable of fulfilling certain specific functions in a battlefield surveillance program. Of primary importance is the detection of enemy targets on the ground, both by day and night. Infrared devices are particularly adapted to the latter.

For the front line soldier, who has as a major problem the detection of enemy personnel at night, there are now available viewing devices which must be used in conjunction with near infrared illumination equipment. Such devices are likely to be of limited future value, however, for it is highly probable that an enemy will have similar devices and would be able to detect our illumination equipment more readily than

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

6-41

we can see our targets. A major effort is required to replace these active devices with passive ones so that interception is impossible. The evaporograph seems especially promising for use by front line troops because of its light weight and simple operation.

For special personnel with front line troops and for observation posts certain passive devices utilizing point by point response detectors (bolometer or photocells) are now available as intrusion alarms, and detectors of warm targets such as tanks and gun barrels. Coupled with radar and narrow beamed infrared light sources (continuous and pulsed), infrared systems show considerable promise in connection with identification, demarkation, and ranging problems. Here again, however, passive image forming devices as the evaporograph, the intermediate infrared and the far infrared image tubes will simplify the techniques and serve many purposes.

Inasmuch as observation by infrared methods is limited both by line-of-sight conditions and ground bases, search from the air allows increased range and often present better atmospheric transmission conditions.

At the present time, units using bolometers are available in mapping devices, and scanning systems utilizing photoconductor cells are available for location of hot objects on the ground. With improved scanning systems and improved sensitive elements as detectors, higher resolution maps should be feasible and perhaps personnel as well as hot objects can be detected. When the other imaging systems (evaporograph,

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

6-42

intermediate infrared and far infrared imaging tubes) become available, thermal mapping utilizing various spectral regions should present an abundance of information as to terrain and location of enemy positions. If these maps taken in various regions of the spectrum are translated into various visible color maps and knowledge is acquired of the emissivity of various objects in the various infrared spectral regions, a trained observer might be able to obtain detailed information for intelligence purposes in a relatively short time. Since this data can be transmitted by radio or infrared communication methods, this information could be assembled at a distant station while the observing station might be a pilotless aircraft.

Infrared communication systems provide a covert and secure means of voice, facsimile and data transmission. These systems which are effective over distances up to approximately ten miles are in a relatively advanced stage of development. Some are available at present and others can be made available in a very few years.

6.62 Recommendations. Included below are two groups of recommendations, general and specific.

6.621 General Recommendations.

6.6211 A number of infrared devices have been developed to the state where they are or will shortly be ready for field test and use. Steps should be taken to explore fully their potentialities in a battlefield surveillance program.

6.6212 Effort should be extended toward the utilization of

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

6-43

infrared techniques in a complimentary manner with other techniques, although the inherent advantages possessed by infrared devices alone, such as light weight, small size, and freedom from complex circuitry, should be exploited also. As a corollary, it may be added that the various infrared techniques should be integrated, whenever possible, into unified presentation devices. (As an example, the integrated presentation obtainable from information obtained by techniques utilizing various regions of the infrared spectrum.)

The Signal Corps Engineering Laboratories appear to have an excellent program toward integration of infrared techniques with themselves and with other techniques. Such efforts should be encouraged.

6.6213 Since Infrared has definite limitation as well as capabilities, effort should be concentrated on those tasks where infrared has excellent capability, but research must be maintained to explore and exploit the entire field. Night viewing and night detecting devices are examples of functions in which infrared can excel.

6.6214 Wherever infrared sensitive elements, or systems are now being developed under the direction of an agency of the Department of Defense, duplication of effort should be avoided in all cases where this work is going on satisfactorily. Instead, implementation of those programs which have a direct application to battlefield surveillance should be encouraged by way of additional financial support with the understanding that increased emphasis shall be given to the possible use, development or improvement of the technique, device,

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

6-44

or system for its application to surveillance.

6.622 Specific Recommendations.

6.6221 Since sensitive elements are the key to the capability of infrared devices, effort should be implemented on improving their sensitivity, stability, and/or efficiency. Specifically,

a. Image Tube. These tubes have apparently been developed nearly to their maximum sensitivity, although the problem of slumpage and cathode instability has not yet been completely solved. In addition, several production problems remain to be solved.

b. Infrared Image Orthicon. Since this tube makes possible television techniques in the near infrared region of the spectrum, its perfection is desirable.

c. Brightness Intensifier. Research should be continued toward developing intensifiers with surfaces sensitive in the 0.6-1.2 micron region for utilizing illumination of the night sky. Two units have recently been delivered to the Navy. The evaluation of these units should be closely followed.

Effort should be extended to developing units, both for vehicle and infrared, which are compact and light weight.

d. Intermediate Infrared Imaging Tube. Research on mirror and beam scanning tubes of this type should be strongly supported to bring them to a point where their ultimate utility can be determined.

e. Far infrared imaging tubes utilizing impurity photoconductors appear to be very promising. This research should be

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

6-45

strongly supported.

f. Evaporograph. Encouraging results have already been demonstrated by this unit. Effort should be implemented to (1) develop sealed off units and (2) to increase the sensitivity or speed of detection of objects near ground temperature. These problems do not appear insurmountable.

g. Lead selenide and lead telluride cells show great promise because of their short time constants, high sensitivity, and spectral range. Research should be strongly supported to improve these cells, and the development of mosaic types for imaging purposes should be extended.

6.6222 Since impurity photoconductors, lead telluride cells, and perhaps lead selenide cells will require cooling, effort should be extended to developing practical cooling systems which can be utilized in operating units.

6.6223 Since many of the imaging devices and point by point detecting devices can be operated to give a video signal output, effort should be directed to the transmission of this data by radio, television and infrared communication techniques.

6.6224 Study and experimentation should be directed to possibility of improved scanning techniques, both mechanical and electronic, especially for use with point by point detectors in mapping and target location devices.

6.6225 Study and experimentation should be made of the possi-

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

6-46

bility of detection of objects at or near ground temperatures with lead selenide and lead telluride cells. If such detection proves to be possible, high resolution maps and the pin pointing of targets may be feasible.

6.6226 Studies should be made of the emissivities of various ground objects and terrain in various infrared wave length regions under various day and night conditions, as quantitative data appears to be lacking in most cases.

6.6227 In view of the possibility of gas or bacteriological warfare, the effort of the Corps of Engineers and the Chemical Corps should be encouraged and perhaps extended in the development of practical infrared systems for gas analysis.

6.6228 Study should be directed as to the possibility of developing coherent sources with the energy concentrated in narrow wave length regions of the infrared spectrum. If such a study reveals a promising method or methods, support should be extended for research and development along this line.

6.6229 Research should be extended to the possibilities of developing new types of photoconductive detectors and to increase the sensitivity of bolometers.

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

CHAPTER 7

ACOUSTICS

7.1 Introduction:

Acoustical methods have been long used for the acquisition of intelligence in battle areas. Among the advantages of acoustical methods are: 1) the fact that nearly all military activities involve the production of sound in air or in the ground, 2) the relative transparency of the atmosphere to sound waves of low frequency, leading to useful transmission at both short and long ranges, and 3) the relative ease of detection of sound waves and their characteristic shapes by electronic devices of great flexibility. The greatest disadvantage to acoustical schemes is the non-homogeneous character of the transmitting media, namely air and ground, and in the case of air, its temporal instability. These are dealt with later in the report.

In this chapter, the application of acoustics to sensing techniques will be summarized under the following headings:

- 7.2) Ranging of enemy sound sources by airborne sound.
- 7.3) Seismic methods.
- 7.4) Identification of enemy sound sources (signatures).
- 7.5) Remote sonic or seismic detection devices.
- 7.6) Sound propagation in air.
- 7.7) Recommendations.

7.2 Ranging of Enemy Sources by Airborne Sound

Artillery sound ranging is the most successful method of securing

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

7-2

surveillance information by acoustic means. The 1st Field Artillery Observation Bn. in Korea has reported that during the months October 1951 - June 1952 more than one half of all locations were made by sound ranging.¹

For ranging on artillery and shell bursts the field forces are now using principally Sound Ranging Set GR-8. This consists of an array of six microphones spaced along a straight line or circular arc base at intervals of about 4 sound seconds, and a recorder to which the microphones are connected by wire or radio links. The record consists of six traces on a continuous strip of paper containing a time axis. The differences in times of arrival of the sound at the various microphones are read off the traces with an accuracy of about one millisecond and transferred manually to a plotting board where the gun position is determined by graphical means. Under good meteorological conditions the accuracy of the set is 100 yards in a range of 10 kiloyards, and the nominal maximum range on 155 mm and 240 mm weapons is about 20 kiloyards. The chief limitation to successful use is the variability of sound propagation through the air. However, crude meteorological corrections are made and in three-quarters of all cases prove helpful. For example, the temperature used in calculating sound velocity is that at 500 feet altitude and is often estimated by adding a correction to the observed ground temperature.

1. Also see Technical Memo. No. T-62, "Sound Ranging for the Field Artillery" Operations Research Office, 15 Jan. 1950.

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

7-3

Wind velocity measurements are based on information which is often four hours old.

It seems clear that the GR-8 set could be improved by replacing manual operations as far as possible by electronic display and calculations. The processing of data and the final fix could be speeded up considerably by automatic methods now available in the electronic art. New methods of handling the meteorological correction are needed and are presently under study.²

Sound-Locating Set GR-6 is now in use against small arms and at shorter ranges (up to 4 kiloyards). It consists of two or more units, each made up of three microphones placed at the vertices of a right triangle with 15 feet sides. Each microphone in a unit is connected by a short wire line to a magnetic tape play back recorder. The units are placed 500 yards apart and are linked by wire or radio communications. The signal, as played back, from each base microphone is compared in turn with the apex microphone in a Lissajous figure method, adjustment of base playback heads being made to provide a straight line on a cathode ray tube. The amount of movement of each of the two base microphone playback heads is proportional to the time of travel of the sound impulse from the particular base microphone to the apex microphone, and the ratio of the two movements is utilized to obtain the sound impulse azimuth by means of a lightweight manual

2. Signal Corps Engineering Laboratories

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

7-4

computer. The azimuths from each unit are transmitted by voice to the control station where the azimuths are plotted. The instrumental accuracy of each azimuth unit is 5 to 10 mils; however, the accuracy realized in the field varies from 5 to 30 mils. This latter variation results from the fact that no correction is currently made for errors caused by wind. The location accuracy is then approximately 5 to 30 yards in 1000 yds. The usable range varies with meteorological conditions and weapon. The nominal range on light mortars is 2000 yards; 4000 yards is about maximum. The maximum range in this system is limited by the technical characteristics of the equipment, including dimensions of the microphone array, length of base lines, frequency response of microphones and amplifiers.

The Signal Corps Engineering Laboratories have in development a new hot-wire microphone element with a cosine law response so that the output is proportional to the component of the wave normal to a particular direction. This will be used in Sound Locating Set AN/TND-1, primarily intended for small arms location. This system functions in a manner similar to the GR-6, in that two or three azimuth measuring stations are employed and the azimuth data are manually plotted at a control station which receives the azimuth information by voice transmission over telephone or radio. The microphone array at each azimuth station consists of two of the cosine microphones oriented at right angles to each other. The detected sound impulses are applied

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

7-5

through filters and amplifiers to the plates of a cathode ray tube, and the sound azimuth is read directly and instantaneously from the face of the tube. To aid in reading, the signal is seen as an intensified dot on the tube face. The advantages of this system are: (a) instantaneous presentation of azimuth data resulting in reduced time for overall system operation; (b) simplicity of azimuth indication permits training of operators in a matter of minutes; (c) no interpretation of signals or data is required; (d) small array (6" dia) permits installation under all terrain conditions and decreases installation time.

Another locating set under development by the Signal Corps is the AN/GNS-1. This is an array of three to five units placed from 700 to 2000 yards apart. Each unit consists of four pick-ups of which two are lined up north and south 150 yards apart, and the other two lined up east and west separated by the same distance. The two lines bisect each other, so that each unit forms a small square array. A magnetic recording play-back unit is used to reproduce the signal from each of the four microphones on a scope in such a way that the time differences in arrival can be readily evaluated with an accuracy of 0.01 second. An electronic clock is used, but the computation of range from the time differences is still performed manually. The major advantages of the systems are (a) the use of independent azimuth measuring units which permits flexibility in location and decreases time required for installation or movement. Locations can be obtained with two or three

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

7-6

units permitting continuance of operation while the other units are moved. (b) The short distance between microphones in each array insures that the microphone signals are nearly identical, thus permitting ease of signal alignment and decreasing the time required to obtain locations. (c) The azimuths as determined from the equipment are independent of the velocity of sound due to the use of ratios of the time differences, rather than absolute time differences. This eliminates the necessity for a temperature correction. (d) Increased range of recorded signal frequencies (5 to 120 cycles per second) permits location on more weapons; and selection of playback frequency bands permits increased signal to noise ratios, and aids in separation of ballistic signals.

Wave front corrugations affect the phase and amplitude coherence of acoustic arrivals at separated points and hence constitute a limitation to the accuracy of any receiving array. Further investigation of the effects of meteorological conditions and terrain on sound propagation is needed in order to arrive at the optimal microphone separation in the array units. Pending such study the figure of 150 yards actually used has been chosen somewhat arbitrarily but with the hope of minimizing corrugation effects.

There is available a personnel detector which consists of a series of microphones (usually about 5 in number) each connected by wire with a central amplifying and monitoring station, (Sound Detector SDD-3/5).

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

The acoustic pick-ups used are sensitive enough to detect a person walking 25 feet from the microphone and are placed in positions near which it is supposed enemy personnel may pass. This device has not been accepted by the Field Forces, principally because of the wire lines which can be followed to the location of monitor by the enemy. It is, however, being used on the Korean battlefield and is reported to be highly successful.³ Seismic pick-ups might successfully replace acoustic ones in this set. This is further discussed in Section 7.3.

The sensitivity of the array devices above mentioned and the signal-to-noise ratio involved could be increased by the employment in the sound reception of the subjective binaural effect.

The location of missile launching sites at ranges up to 10 or 20 miles may be feasible with air borne sound ranging. However, this would appear out of the question at ranges of 200 miles or more. Acoustic ranging on the missile in flight, though difficult, should not be excluded from consideration (Cf. Sec. 7.4 on long range acoustic detection of aircraft). It appears, however, that the use of remote sensing and repeating devices (Sec. 7.5) offers more hope here.

7.3 Seismic Methods:

Seismic techniques, that is, ground carried wave techniques, may be useful in battlefield surveillance. Perhaps the greatest factor limiting the usefulness of seismic methods is the fact that distance

3. Project Tacit

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

7-8

and location measurements are both greatly affected by the terrain through which the waves are carried. In order to determine accurately either distance or location it is necessary to know the velocity of transmission of seismic waves through and the thickness of the various geological formations along which the waves are propagated. This means that either the geological structure of the area must be accurately and completely known or that velocity test programs must be undertaken, a situation not normally practical under battlefield conditions even when possible.

A second factor which frequently causes difficulty in seismic measurements is the variation of the impedance of the ground to the transmission of seismic waves in the vicinity of both the source and the receiver. The amount of energy required to obtain a useable record at a fixed distance may vary by two or more orders of magnitude depending upon ground impedance.

Despite these limitations there are several places where seismic methods, active or passive, can possibly be of some help to the military. Within the active classification fall all methods using an artificial disturbance controlled by the operator of the equipment and created with intent of measuring the effects of the disturbance. The passive classification includes measurement of the effects of disturbances over which the operator has no control. Passive methods are, then, essentially listening methods. Active methods include the use of seismic waves for communication and for navigation. Communi-

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

7-9

cation over limited ranges can be accomplished by seismic waves. This might possibly be advantageous in such applications as remotely arming, disarming, or exploding land mines. Neither communication over long distances nor accurate determination of position by seismic wave travel times seems feasible.

Passive techniques appear to hold somewhat greater promise for surveillance than the active methods. The former have long been used to determine enemy construction activities such as trenching. These applications are well known and probably are of limited use in modern warfare. Other possible passive applications include: listening for enemy patrol personnel and detection of moving enemy trains, tanks, and other vehicles, and mass movements of troops. Men walking in the vicinity of buried seismic detectors (geophones) can be detected at distances of from 50 to 150 yards. While this has been known to the armed forces, the technique has not been formally accepted, due to the use of wire communication in the devices developed to date. It appears feasible to use other methods of communication such as infrared, radio or ultraviolet waves to accomplish the required communication without the use of wires. Special possibilities will be discussed further in Sec. 7.5. Such a detection system would seem to be of great value in guarding against enemy patrol infiltration.

Enemy movement of tanks or other vehicles and of large masses of troops can be detected by seismic means. No data were found by Project TEOTA on the ranges at which detection can be reliably made, but it is

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

estimated that detection might be accomplished at ranges up to a maximum of 10 miles with fair reliability under favorable circumstances for large mass movements.

Research work recently begun at the National Bureau of Standards bears on the subject of seismic transmissions. One program, sponsored by the Office of Ordnance Research, is concerned with the direct measurement of phase velocity and attenuation for sound waves propagated through soils up to distances of the order of three hundred feet. An electrodynamic vibrator (MB type C5 or its equivalent) will be used as a source, and vibration gages and/or geophones, with an amplifying and recording system, will be used for detection. The experimental data are to be coordinated by a concurrently developed theory of the near radiation field from a point source on the surface of a semi-infinite elastic solid. The plan is eventually to measure various types of soils in situ. For the loose type of filled earth overburden studied so far, the velocity amplitude falls off rapidly with distance from the source. Also, the higher frequencies are attenuated much more rapidly than the lower frequencies.

7.4 Identification of Enemy Sound Sources:

It has been found recently that visual presentations are of considerable aid to the ear in detecting and identifying characteristic sounds, as of approaching aircraft, tanks, etc. In this section is described work of this kind done at Bell Telephone Laboratories, as well as pertinent research now underway at the National Bureau of Standards.

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

7-11

7.41 Bell Telephone Laboratories. Signatures of a number of different machines have been recorded by the Lofar - an automatic wave analyzer of the heterodyne type. In the model standardized, the frequency range 0 to 150 cps is scanned every two seconds by a filter effectively one cycle in width. The result is presented on Teledeltos paper as a plot of frequency against time with the energy distribution throughout the spectrum indicated by the relative darkness of the plot. A fast acting automatic gain control operates over a band of 15 cps, at which the scanning band is centered. Rate of travel of the lofargram is normally 9 inches per hour. The detection of any line structure in the plot is helped by the close spacing of successive scans and by visual integration. Both the rate of paper travel and the frequency range analyzed can be altered over wide ranges by corresponding changes of gears within the equipment.

Analysis of the Doppler effect presented on the lofargram under suitable conditions yields a number of signature characteristics. These include the speed of the vehicle or aircraft involved, the ranges of detection both inbound and outbound, and the distance of closest approach to the pickup device - microphone or geophone. To facilitate calculations, charts have been prepared which relate these characteristics to two quantities: the ratio of the two limiting Doppler frequencies, and the time needed to pass from one of the limiting frequencies to the other at the maximum rate observed.

Signatures of propeller-driven planes are confined mostly below

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

600 cps, with the strongest lines usually below 200 cps. The spectra in general are made up of two harmonic series, one with a fundamental corresponding to the propeller blade rate, the other with a lower frequency fundamental corresponding to the cylinder exhaust rate. These are superposed upon the more or less random wind noise. Relative amplitudes of the lines depend upon aspect as well as upon detailed engine, body, and propeller characteristics. Propeller blade harmonics are distinguishable up to higher frequencies usually than are the exhaust harmonics.

Ranges observed on commercial planes vary with the sound output of the plane, its height, and wind and weather conditions. A set of thirty signatures of commercial planes, gathered over four days, gave ranges from little over two miles up to seventeen miles. Greater ranges in general were found on the one day out of the four during which there was a temperature inversion at the ground. The ranges taken from lofargrams were greater than those observed by ear.

Increase of signal strength was had through use of a horn originally built for microwaves. Signal to noise ratio is thereby improved when background and interfering sources are distinct in angle from that of the signal source. Thus in one example the range with the horn was 18 miles, while the range with a twin microphone alone was 6-1/2 miles. The gain of the horn was 10 db at 100 cps and 16 db at 200 cps.

The lofargrams of the planes discussed above carry interfering traces produced by motor traffic. These traces are prominent in the

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

7-13

range from 50 cps to 150 cps, the most intense lines appearing sharply inclined when gears are shifted. A bulldozer signature was made up of the fundamental of about 35 cps with weaker second and third harmonics. Another diesel signature included a number of harmonic bands of the order of 3 cps wide. The fundamental was about 12 cps, and the bands were strongest from 60 to 130 cps.

A jet plane signature looks like a band of random noise with no line structure apparent. The band extended up to an emitted frequency of 800 cps roughly, beyond which the energy fell off rapidly. A somewhat more useful picture is produced by two spaced microphones in series which yield an interference pattern. In this way the ranges can be more readily deduced since the pattern then can be distinguished more readily from the noise background.

The signature of a light tank M4 was followed out to a little more than a mile, as picked up by geophone. The intervening soil in this test, it should be noted, was decidedly sandy. A single line in the neighborhood of 30 cps composed the signature.

Microphone housings have been developed to permit installation in the field without significant deterioration over time intervals of the order of months. For this purpose the microphone is enclosed within a loosely fitting plastic bag sealed against moisture. This is suspended by butyl rubber strips within a perforated metal cylinder. The whole is wrapped within a blanket of hair felt $3/4$ " thick. Up to 700 cps the response of the microphone in its housing is within one db of the

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

7-14

response of the microphone alone. Losses up to 5 db or so are found at frequencies up to 3000 cps. Comparative tests show that the hair felt wrapping provides an effective wind screen. Associated with feedback-stabilized amplifiers, the installation has operated satisfactorily for months, unattended.

Fabrics other than hair felt provide protection and transmit effectively below 300 cps. These include rubberized cloth, canvas, and waxed canvas. At higher frequencies however, the losses introduced are decidedly greater than those of hair felt, reaching 20 db.

Comparative tests were carried out with twin microphone structures, one mounted on top of a 100 foot tower, and the other at the tower base. Airplane signatures came in with somewhat greater intensity from the microphone at the tower top. The signal to noise ratio however was distinctly greater from the microphone at the base, even when the wind velocity at the base was fairly small. For subsequent experiments, accordingly, the microphone structure was placed at the ground level.

Two circuits have been designed to signal the passage of propeller driven planes. The first makes use of the harmonic structure of the airplane signature. It consists of a filter passing a band from 60 to 200 cps, a full-wave rectifier, a 30 cps low pass filter, a limiter and a frequency meter. The second makes use of the pronounced drop in frequency, associated with the Doppler effect, of any selected line of the signature. The microphone input enters a modulator which is supplied with a beat frequency by a multivibrator. The output of the

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

7-15

modulator is fed to a narrow band filter, a limiter, crossed slope circuits, and rectifiers. The rectifier output serves to modulate the frequency of the multivibrator. The feedback loop thus constituted tracks the selected line by keeping the modulator output frequency roughly centered in the band filter. An auxiliary input oscillator fixes the frequency roughly at which tracking starts. Test results show that while the first circuit is substantially the simpler, it provides a less accurate picture of events than the second. In both cases the range over which operation is assured is less than the range of visual detection observable on the lofargram.

With two velocity microphones mounted at right angles aircraft bearing indications were observed on a cathode ray tube. A pressure microphone connected to the GRO gun was used for sensing. The bearings were in general agreement with visual sights. The useful range of the indicator was inferior to that of the lofargram because of background noise. Tracking circuits of the kind mentioned above for propeller planes would improve this situation.

7.42 National Bureau of Standards. One of the researches carried out in these laboratories for the U. S. Marine Corps is concerned with military characteristics for remote sensing devices. The immediate objective of one phase of this work is the determination of various characteristics of the acoustic and seismic radiation fields generated by military sources. Characteristics under investigation include energy levels, frequency spectra, radiation patterns, etc. One task,

SECRET
SECURITY INFORMATION

SECRET

7-16

for example, is the measurement of the airborne levels at various distances from such sources as marching men, trucks, jeeps, tanks, artillery prime movers, construction operations, etc. Sound level readings will be supplemented by recordings made on magnetic tape. From the recordings, it is planned to determine the waveform characteristics of the various airborne sounds. Another task will involve a similar investigation of the ground vibrations produced by military sources. Data obtained from these studies will then be used as a basis for the design of acoustic sensing devices to monitor activities in enemy territory from remote positions.

Another research program now underway might be directly useful to the TEOTA program, although the objectives differ from those under TEOTA. In connection with a project sponsored by the Ordnance Corps of the Department of Army, a study is being made of the ground vibrations which are produced by moving tanks and other military vehicles. These vibrations are propagated in part along the surface of the overburden. The measurements were made with MB vibration gages which were buried usually about 18 inches below the surface and at various distances from the line of travel. By burying three properly orientated gages at the same point, and using a multichannel recorder, all three components of the velocity signature were obtained simultaneously.

One of the results from a large number of measurements on a number of representative tanks, both American and foreign, operated at various speeds was that the observed predominant recorded frequency was the

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

7-17

same as the calculated tread repetition rate. Also, careful analysis of the records from gages placed close to the line of travel showed evidences of a shift in frequency due to the Doppler effect. The presence of a measureable Doppler shift was due to the relatively slow velocity of sound, about 500 feet per second through the overburden.

The vibration energy transferred to the overburden by a moving tank is quite large. Peak accelerations of 2 to 3 times gravity were obtained for a tank moving at about 25 miles per hour. Allowing for the considerable attenuation of sound propagated through the overburden, values of acceleration of 2 to 3 times gravity measured close to the tank indicate the tank signature can be detected at considerable distances from the tank. The distances will, of course, vary with the type and condition of the overburden.

In connection with the problem of acoustic detection of aircraft, it may be pertinent to mention that on several occasions signals of about 3 to 5 cps was recorded from aircraft passing over a microbarographic system set up for a national defense agency. Since the upper cut-off frequency of the system is about 4 cps, no information was recorded at high frequencies. It is suggested, however, that in the detection of air-craft it might be beneficial to extend the frequency range of the measuring equipment to much lower frequencies than that of the conventional microphones used at present.

7.5 Remote Sonic or Seismic Detection Devices

It appears desirable to provide an expendable device capable of

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

detecting sonic or seismic disturbances and relaying information about these disturbances to a central location. There are at least two specific instances in which such a remote detector might prove to be tactically useful; first as a supplement to the eyes and ears of an observer in a forward position. Small receivers capable of detecting the sounds of infiltrating enemy personnel could be used to extend the range of surveillance of an individual. Second, a sonic or seismic detector which could be placed beside a road or near an intersection could be used to relay information about the density and timing of traffic on that road to an artillery position capable of firing to the previously selected target position.

The principal problems involved in such a remote detector are: first, placement of the detector at a known location; second, providing an adequate power supply; and third, finding a satisfactory method of relaying information back to the control station. Placement of a detector at an appropriate location offers no great difficulty in the case of an observer in an advanced position, provided the size and weight of the individual units can be kept small enough so that a man could carry several of them. In the case of a traffic detector, placement by reconnaissance patrol is perhaps conceivable but is probably not very practical, except under special circumstances. Alternatives are placement by a predicted fire projectile or by an aircraft. In either of these cases size and weight of the detecting device are extremely important, as well as the ability of the detecting device to

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

7-19

withstand launching and landing shocks. It is known that simple vibration detectors have been used successfully in line mines and underwater mines designed for launching by parachute from an aircraft. The German "Butterfly" bomb descended slowly by rotating blades to the ground and was later fired by a vibration switch. Also the German Naval acoustic mine was able to withstand water entry after a parachute drop. It is not known whether an acoustic detector has been built which can stand the accelerations involved in the firing and landing of a non-explosive projectile. Presumably, however, with proximity fuse techniques such a device could be developed.

The second major problem is one of power supply. To be useful, a remote acoustic detector should have an endurance of several days or preferably weeks. The Navy uses remote acoustic detectors for submarine detection. These equipments, known as sonobuoys, include a hydrophone, an audio amplifier, a radio transmitter and a power supply. One type is designed to operate for a period of about six weeks without maintenance but the battery compartment is about the size of an oil drum. The second type of sonobuoy is expendable, and is of a more reasonable size. For example, the AN/SSQ-2 consists of a wide band omni-directional hydrophone, an audio amplifier, a radio transmitter, and a radar beacon which operate continuously. The entire package, including power supply, is 36 inches long and about 5 inches in diameter and weighs about 16 pounds, of which approximately 4 pounds is battery. The life of this buoy is one hour. Since the required

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

7-20

size for useful endurance is too great for the proposed Army use, it seems clear that a remote sonic detector is feasible for the Army only if it can eliminate the large power drain of a continuously operating audio amplifier and radio transmitter.

Within this limitation, however, several possibilities remain. For example, a sound or vibration powered detector might be used to modulate the impedance of a radar reflector. A mechanically resonant reed might be used to close an electrical contact which would make a significant change in the tuning of a radar reflector. This system would eliminate the power supply problem, but would probably encounter difficulty relaying information from the detector to the control station. Another possibility is to use a sound-powered or vibration powered detector to key the operation of a radio transmitter. The useful life of such equipment would approach the shelf life of the battery, rather than the relatively short life under high load. In addition, transistor circuits could be used to minimize the power drain.

The third problem concerned with a remote acoustic or seismic detector is that of returning the signal information to a control center. For tactical reasons it is impractical to consider the use of ground wires even for relatively short runs. Preliminary consideration of the proposal for a modulated radar reflector shows that this scheme encounters difficulties in the ability of existing radar equipment to detect a small modulated target in the return from a large ground patch. The possibility of transmitting radio signals during the time that the

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

7-21

detection device is actuated is technically feasible but may suffer from the military disadvantages of (a) radio spectrum crowding and (b) possibility of jamming. In the case of the anti-infiltration detector, transmission is desired only over a few short ranges, of the order of a hundred yards or so. This might be accomplished at very low radio frequencies, by means of inductive coupling between the transmitter and the receiver. Use of such a frequency would reduce the problem of spectrum crowding since these frequencies are not used by most types of military communication systems. Alternatively, actuation of the vibration switch could be used to trigger a visual flash of a characteristic color or pattern of light intensity versus time.

In summary, it is believed that two types of remote sonic or seismic detectors are technically feasible. One of these would be used to extend the hearing range of a front line outpost to detect infiltrating enemy personnel. The second would be placed beside a road to detect the passage of heavy vehicles. In both cases the acoustic detection range would be limited to perhaps 50 yards. The acoustic detector would probably be a resonant mechanical system which would open and close an electrical contact when the amplitude of vibration in a specified frequency band exceeded a preselected level. Closure of the electrical contact could trigger a radio frequency oscillator which could be detected at central control station, or could generate some other type of characteristic signal.

In connection with the problem of locating acoustic sensing

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

7-22

devices in enemy territory, it has been suggested that it might be feasible to support the device on a balloon over the area to be monitored. This method of surveillance, if feasible, would be best suited for use at night or during times when the area is fogbound. The use of a captive balloon is obvious. However, it may be possible to develop a self capturing or an altitude operated valve which would maintain a free balloon at a pre-determined height. It is believed that the use of a balloon supported sensing device would cover much greater areas than is possible with devices located on the ground because of the attenuation of sound by surface and/or obstacle absorption or deflection. Also, the difficulty of the problem of telemetering signals to an observation post might be greatly reduced.

7.6 Sound Propagation in Air: Limitations imposed on acoustic methods by the properties of the medium.

In evaluating the possibilities of surveillance techniques, it is important to consider the transmission properties of the medium. Due to transmission losses the character and overall level of a sound spectrum from a given source will depend on the distance from the source at which the spectrum is to be detected or identified. In the case of air as the medium, transmission losses are partly predictable because of results established from scientific experiment and theory. Much less is known about transmission through the ground. In this section the present status of knowledge concerning transmission losses in air will be briefly summarized.⁴

4. A USAF sponsored project is underway at Brown University, whose initial purpose is to survey the existing literature on propagation of sound over land.

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

7-23

The following physical mechanisms for transmission loss must be considered:

- a) Divergence loss, due to spreading of sound waves in a homogeneous atmosphere.
- b) Absorption loss due to the air itself, because of viscosity, heat conduction and thermal relaxation.
- c) Absorption-scattering loss due to presence of suspended particles or droplets, as in smokes or fogs.
- d) Terrain loss, due to "absorption" by the ground or ground-covering.
- e) Scattering due to small scale temperature or wind inhomogeneities, resulting from instability and turbulence of the atmosphere.
- f) Refraction loss, due to steady, large scale gradients which produce sound "shadows".
- g) Loss due to high amplitude sound propagation.

Of the classes of losses listed above, presently available scientific knowledge allows (a) and (b) to be estimated rather well for given meteorological conditions, though further laboratory investigation of (b) is advisable, especially at very low frequencies (above and below 10 cycles/sec). Some information about (c) and (d) is available from theory and experiment, but further practical data in regard to fogs, smokes and terrain properties are needed before accurate predictions can be made about losses under actual conditions.

It is well known that (e) and (f) are important causes of trans-

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

7-24

mission loss, but neither theory or experiment permits estimations of these losses for given conditions with any accuracy. High amplitude loss (g) occurs only in the vicinity of intense or explosive sound sources. Both laboratory and field data are available, but understanding of the problem is far from complete.

As an indication of the probable importance of the various loss mechanisms a few typical calculations are given below for those cases, namely (a), (b), (c) and (d), where losses may be estimated with reasonable confidence. Values are given for the loss (ΔL) in sound level to be expected for sound travelling from a point 10 yds from a source to a distant point R yds from the source.

a) Divergence loss. At low frequencies in a homogeneous atmosphere over a rigid ground surface the main loss will be due to (a) and will therefore be essentially independent of frequency and weather conditions. For most sound sources an inverse square law intensity-distance relationship will be followed beyond 10 yds. Results are given in Table I for ranges of 1 and 10 kiloyards.

b) At high frequencies (in a homogeneous atmosphere and over a rigid boundary) mechanism (b) will be important; this loss is independent on the frequency as well as on meteorological conditions, (i.e., on temperature and humidity). Losses from this cause are given in Table 7-1, calculated from classical absorption theory and from molecular absorption theory. In general, experimental results in the laboratory (for moderate humidities) agree rather well with these theories

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

7-25

for frequencies above about 1 kc. Lower frequencies have as yet not been adequately studied. The losses cited are for different frequencies and ranges, but for only one set of weather conditions. Wide variations in the losses may be expected for different temperature and humidities.

Table 7-1. Transmission losses due to various mechanisms

<u>Mechanism</u>	<u>Range (R)</u>	<u>Conditions</u>	<u>Frequency</u>	<u>Loss (ΔL)</u>
(a)	1 kyd			40 db
	10 kyds			60 db
	100 "			80 db
(b)	1 kyd	Temperature: 15°C Relative Humidity: 50%	10 kc/sec	90 db
			3 kc/sec	9 db
	10 kyd		3 kc/sec	90 db
			1 kc/sec	10 db
	100 "		1 kc/sec	100 db
			0.3 kc/sec	9 db
(c)	10 kyds	Fairly dense fog	0.2 kc/sec	up to 160 db
			0.03 kc/sec	up to 120 db
		Fairly dense smoke	1 kc/sec	up to 80 db
			0.5 kc/sec	up to 25 db
(d)	1 kyd	Porous earth		up to 40 db
	10 kyd			up to 60 db
	100 kyd			up to 80 db
.....				

(c) If there is fog or smoke in the air, losses will result which will be particularly important at low frequencies, where the contribu-

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

7-26

tion due to (b) is small according to the above calculations. From laboratory data we obtain results given in the table.

(d) If the ground over which the sound passes is porous, an additional loss results. This "boundary loss" may be calculated provided certain acoustical characteristics of the earth or ground covering are known. Values given in Table 7-1 represent upper limits to this loss; such high values obtain if the ground is sufficiently porous and the frequency is sufficiently high, say, above 2 kc. At lower frequencies the loss will usually be less.

In drawing conclusions from Table 7-1 it is reasonable to assume that in most cases a receiver will not detect a given source if the transmission loss (beyond 10 yds) exceeds 160 db. (In many cases, the permitted transmission loss will be very much less). If only losses (a) and (b) are important a range of 100 kyd may presumably be expected for low frequencies, the upper limit being just below 1 kc/sec. If the earth is porous the upper frequency limit may be much lower. Appreciable amounts of fog may make such a range impossible at any frequency. Mechanisms (e), (f) and (g) will, of course, shorten ranges even more. Much more knowledge is needed before ranges can be predicted with accuracy.

7.7 Recommendations:

A number of specific recommendations follow.

a. Program should be undertaken to improve existing type systems and equipments by:

1. The replacement of manual computation and plotting processes by automatic electronic arrangements.

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

7-27

2. The use of the subjective binaural effect to improve the signal-noise ratio in listening devices.

3. The reduction of wind and ambient noise by known techniques.

4. The adaptation to air use of the long range listening arrays developed for underwater sound detection.

b. The acoustic signature technique should be exploited for military applications by:

1. A measurement program of the acoustic signatures of all military noise-making devices under the widest possible variety of conditions and down to very low frequencies using the LOFAR type equipment, and training observers in its employment.

2. Investigation of methods of improving the fidelity of signatures and increasing the details of presentation.

c. Seismic detection should be investigated for possible military application by:

1. Systematic experimental and theoretical studies of seismic propagation from military sources both over short and long ranges.

2. Development of prototype equipments for field evaluation.

d. A program be encouraged for the systematic studies of the propagation of sound in air as affected by terrain and meteorological conditions, particularly in the low frequency range (from 0.1 to 1000 cps). This should include methods for lessening errors in sound ranging due

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

7-28

to meteorological conditions, study of amplitude-phase correlation in received sound signals, the use of calibrating shots or planted sources, and ranging on projectile sounds.

e. A comprehensive program should be initiated of the development and field evaluation of a sound-detection system based on devices along the lines suggested in par. 7.5.

f. Reconsideration of military usefulness of existing acoustic personnel detectors of the SSD3/5 type is recommended.

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

CHAPTER 8

WEATHER

8.1 Introduction:

The state of the weather is of extreme importance on the battlefield. Advantage is often taken of poor "seeing" weather to move troops and supplies, since the lack of visual or photographic reconnaissance capabilities provides some element of security not possible in clear weather. Reliance must be placed on infrared, radar, and other non-optical detection devices for detection in the presence of low-flying clouds, fog, or poor visibility or illumination. For maximum efficiency of detection, the technique should be selected in accordance with the present or expected weather conditions, since the inherent capability of each technique is limited, and in some cases is weather sensitive. Consequently, weather intelligence at the disposal of the commander to permit the choice of the optimum surveillance techniques is most desirable. Once available, weather intelligence will be valuable for many other uses on the battlefield.

Preparation of weather intelligence for battlefield use will require observations of cloud cover and height, visibility, illumination, temperature, precipitation, ground conditions, river stages, and wind in forward areas and behind enemy lines. Changes in these elements will also need to be anticipated for a period of perhaps 24 or 48 hours in the future. But before a picture of current weather or a prediction of future weather can be prepared with any degree of assurance, it is essential that as complete a collection of necessary

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

8-2

weather observations be made as battlefield conditions will permit.

The discussion to follow will consider the pertinent topics concerning weather and weather observations. The important topics are:

- a. Conventional weather and auxiliary observations
- b. Radar weather observations
- c. Weather forecasting
- d. Weather control
- e. Atmospheric detection of the enemy

8.2 Weather Techniques

8.21 Conventional weather and auxiliary observations include surface and upper air observations of pressure, temperature, humidity, and winds made by surface observation equipment and balloon-and airplane-borne equipment. In addition, observations are made of precipitation amount, cloud cover and height (both from surface and aircraft), visibility, illumination, soil condition and trafficability, river stages. The conventional weather equipment currently in use, recently developed equipment in the procurement stage, new equipment under development, and proposed developments are listed.

8.211 Conventional Weather Equipment Currently in Use. This includes (1) the surface observation equipment (e.g., for measurement of pressure, temperature, moisture content, wind, precipitation). (2) upper air observation equipment (e.g., pressure, temperature, moisture content and wind as obtained by means of balloons or balloon-borne equipment), (3) weather reconnaissance equipment for measuring ambient

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

8-3

conditions along flight path by means of aerography type equipment and below flight level to the ground by means of parachute radiosonde, and (4) cloud height equipment such as ceilometers. Special assemblies or meteorological stations such as mobile weather stations and packaged weather stations are also available as are visibility and illumination meters and cone penetrometers for measurement of soil trafficability.

8.212 Recently Developed Equipment in Procurement Stages. The equipments in advanced stages of development or in the production stages are listed in Table 8-1. These equipments include provision for measuring surface pressure, temperature, humidity, winds, precipitation, and ground temperature.

TABLE 8-1

Meteorological Equipment in Procurement Stage

Meteorological Station AN/PMQ-1	
Meteorological Station AN/PMQ-4	1952
Naval Aerological Indicator NAX-7-47	1953
Wiresonde Set AN/UMQ-4	1953
Temperature-Humidity Measuring Set AN/AMQ-7	1953
Wind Measuring Set AN/MMQ-1 (XE-1)	1953

8.213 New Equipment Under Development. Equipments under development for measuring height of top and bottom of clouds, wind data, temperature, pressure and moisture content, are listed in Table 8-2.

TABLE 8-2

New Equipment Under Development

Cloudsonde	1956
Improved Wiresonde Set	1957
Aerograph Set AN/AMQ-5	1956
Radiosonde AN/AMQ-6	
Micrometeorological Set AN/PMQ-2	1953
Automatic Weather Station	

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

8-4

8.214 Proposed Developments. A number of equipments are currently being considered. These include principally the following:

8.2141 Autosonde.

(a) Automatically measures upper air temperature, pressure, humidity from automatic weather stations.

(b) Application - same as automatic weather stations.

8.2142 Coptersonde.

(a) Measures temperature, humidity and winds below flight level of a helicopter to the ground. Sensing elements are lowered by means of cable and data telemetered to helicopter via cable or radio or data recorded.

(b) Application - similar to Wiresonde except maneuverability of helicopter permits sampling at many more locations as well as moving to sampling areas more rapidly.

8.2143 Parachute Automatic Weather Stations SQM-18 and AN/GMT-1.

(a) Measures surface temperature, pressure, winds after being parachuted to the ground. Measurements made at fixed intervals and data transmitted to receiving station by radio. Station capable of operating for 1-2 weeks without manual attention.

(b) Application - obtain weather data in enemy territory.

(c) Remarks - The project at SCEL is in process of being cancelled. However, the instrumentation for the experimental equipment is 90% complete. The Navy recently completed development of a similar station at NEL. Both service tests on this station are not conclusive -

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

8-5

present status unknown - may go back into development or limited procurement made with changes. The project at SCEL has alternated between "hot" and "cold" for years. The equipment considered quite expensive for its limited life. The transmission range of station is limited to line-of-sight and reception is unreliable for long distances.

8.2144 Transosonde.

(a) A system for measuring vertical cross section of atmosphere at prescribed times from level of constant level balloon to ground. Parachute-borne sondes are released from a balloon, which transmit meteorological data to a receiver on balloon where the intelligence is retransmitted to receiving station. Winds at balloon level obtained by tracking balloon position.

(b) Application - measurements of meteorological data over ocean areas, isolated regions, or enemy territory. The latter application is particularly important since aircraft reconnaissance over enemy territory may not be practicable.

(c) Remarks - The Navy has been working on this although the present status is not known. A number of groups, including N.Y.U., NRL, General Mills, Winzen and Signal Corps have worked on constant level balloons. The Japanese used constant level balloons during World War II. It is believed that only wind data may be obtained by direction finding techniques.

8.2145 Light Aircraft Weather Equipment - aerograph equipment AN/AMQ-7 which is in procurement for installation on USAF weather

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

8-6

reconnaissance aircraft should be redesigned for installation on Army aircraft for weather observations over nearby enemy territory.

8.22 Radar Weather Observations. Radar has proved most useful in detecting precipitating clouds within 100 to 200 miles and in locating cloud layers aloft.

a. Radar set AN/CPS-9, designed primarily for detection of precipitation echoes is in production but on account of its large size, it can only be used efficiently in semi-permanent sites in rear areas. Since in rugged terrain its "view" of the weather over the battlefield may be blocked by hills and mountains, development of a lightweight, mobile radar, designed for front-line use and capable of detecting precipitation echoes to 100-150 miles is required.

b. Radar set (AN/TPQ-6) detects tops and bottoms of clouds above the set. A light weight, mobile redesign of this set would be useful for vectoring aircraft over the battlefield to take best advantage of existing cloud layers.

8.23 Weather Forecasting

8.231 Local Weather Analysis. When all the local observations of the current state of the atmosphere, surface conditions, and river stages have been gathered together and plotted on the battlefield weather chart, there remains the task of making an analysis of the data and then a forecast of future changes. The weather analysis consists of a pictorial representation of the distribution of cloud, precipitation, winds, visibility, and temperature, followed by an attempt to

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

8-7

explain the observed patterns in terms of large-scale weather features, such as highs, lows, fronts, and in terms of local features of terrain, day and night influences, and land-water configurations.

8.232 Broad-scale Weather Analysis. The local analyst should have available a map of the current and expected large-scale weather features which he can use as the meteorological background for interpretation of the local weather characteristics. Such current and prognostic weather charts are prepared at USAF weather stations and should be transmitted to the local weather forecast unit by facsimile equipment AN/TXC-1.

8.233 Local Weather Prognosis. After the forecaster has completed his analysis and diagnosis of the current weather elements, he is in a position to project into the future the expected changes. The forecaster should attempt to give as detailed an account as possible over the battlefield of cloud, precipitation, wind, temperature, visibility, state of the surface, (dry, mud, snow, etc.), trafficability (including river crossings), and their expected changes within the next day or two. This detailed forecast over a small area comparable to that of a battlefield presents a rather different problem to conventional meteorologists whose experience has been mostly in preparing less detailed forecasts over larger areas; some meteorologists have recently begun to acquire experience in detailed localized weather predictions over quite small areas such as an agricultural field, forest, large industrial site, or a city.

8.24 Weather Control. This has been the subject of increased

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

8-8

activity in recent years, but much remains to be done before the modest results achieved thus far can be exploited for battlefield use.

8.241 Cloud Dissipation. Recent experiments have shown that under certain conditions cloud sheets may in part be temporarily dissipated. Only supercooled stratus clouds, that is, flat clouds a few hundred or thousand feet thick and composed of water droplets existing at temperatures below freezing have so far proved to be in any degree susceptible to dissipation by seeding. Seeding of such clouds from above by dry ice has in some cases produced holes or trenches in the clouds which persisted for many minutes. However, firm criteria descriptive of supercooled clouds which may be dissipated artificially are still not known. Once these criteria have been established, it would be possible from climatic cloud data available, to delineate those areas over the world where cloud dissipation might have a reasonable chance for success.

8.242 Fog Dissipation

(1) FIDO. Some success in burning off fog by burning large quantities of fuel (FIDO) have been achieved, but on account of its cost, limited effective area, large fuel expenditures, and possible tactical disadvantages, it is not considered suitable for battlefield fog dissipation.

(2) Supercooled Fog. When the fogs are composed of supercooled water droplets, they should respond much as supercooled stratus clouds do when seeded, and so experimental criteria established for

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

8-9

stratus should apply to fog, except possibly in the speed at which new replacement fog is formed.

(3) Warm Fog. Chemical, electrical, sonic techniques of dissipating fog at above freezing temperatures have been attempted in the past with little or no success. This research should be reviewed and the promising lines vigorously pursued.

(4) Ice Fog. When temperatures drop below -40° and there is a source of moisture, such as from chimney smoke, from an exposed body of water, or exhaled air from animals, an ice crystal fog is likely to form. This is a very shallow fog, but dense enough to interfere seriously with aircraft and ground operations. At present, there appears to be no practical method of dissipating ice fog, but this problem is receiving study by the Stanford Research Institute under USAF contract.

8.243 Artificially Induced Precipitation. An armed unit which could produce rain at will would have a distinct advantage over an enemy. However, whether it is possible to precipitate clouds artificially has been the subject of much recent controversy and very few convincing conclusions have emerged. All factions agree, however, that if precipitation is to be induced, it will require special cloud conditions which are quite close to natural precipitation and that it will be virtually impossible to pin-point artificially induced rain or snow showers over a target area smaller than some thousands of square miles.

8.244 Thunderstorm modification has been investigated by Dr. E. J. Workman of the New Mexico School of Mines under a Signal Corps contract.

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

8-10

He has been investigating the mechanism of electric charge formation in thunderstorms. His studies have indicated that the sign and intensity of charge of freezing water can be modified strongly by addition of extremely small amounts of contaminants. The implication of his work is that ultimately it may be possible to control the intensity of thunderstorms, either to dissipate or intensify them.

8.245 Artificially created clouds would be useful as a substitute for smoke screens or as a reflector for battlefield illumination. Clouds have already been produced artificially in the form of condensation trails by high-flying aircraft or by smoke and water vapor effluent. Both types of cloud formation require extremely low temperatures in which the addition of moisture will produce saturation sufficient to form clouds. Some cases of ice cloud formation have occurred as a result of dispersal of dry ice but again these seemed to be under unusual meteorological conditions. It does not appear worthwhile to investigate artificial cloud formation for battlefield screening.

8.246 Artificial illumination of the battlefield. It has been suggested (see Project VISTA report) that dispersal of sodium in the high atmosphere would enhance the sodium D lines in the night light from the sky (airglow) and thus increase illumination. To illuminate an area the size of greater Los Angeles would require a ton of sodium and this would present a formidable problem for rocket lift.

8.25 Direct Detection of Enemy by Atmospheric Effects. There exist possibilities of detection of enemy concentrations, movements, and

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

8-11

stock-piling by passive atmospheric sensing techniques.

8.251 Atmospheric Ionization. The Navy has successfully conducted experiments in detection of land, air and water vehicles by sensitive measurements of increases in atmospheric ionization caused by exhaust gases. This technique should be investigated for land and air vehicles.

8.252 Nuclei Detection. Vonnegut (General Electric Company) has investigated the possibility of detecting exhaust gases of vehicles by measuring increases in condensation or sublimation nuclei, and preliminary tests seem quite promising.

8.3 Recommendations:

These are given on the basis of time required for completing the particular phase of the work.

8.31 Immediate (0-2 years)

8.311 Personnel.

1. Meteorological specialists in detailed small area weather forecasting should be assigned immediately to the forward areas in Korea to serve as the connecting link between battlefield weather observations and broad-scale weather charts. These specialists should specify the type and location of weather observations required to prepare battlefield forecasts and should have available the large-scale USAF weather charts for current use.

2. Since there exists only a small number of meteorologists with experience in detailed small area forecasting, additional meteor-

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

8-12

ologists should be given lectures, laboratory and field training in micro-meteorology, where particular emphasis will be placed on terrain, day-night and land-water modifications of the large-scale weather pattern. Instructors for this course should, if possible, be drawn from those who have had actual experience in micrometeorological forecasting, including battlefield experience. This training program should be a continuing one, designed to incorporate the results of the latest micrometeorological researches and battlefield experiences in the lecture, laboratory, and field work.

3. Training of weather observers in the use and maintenance of conventional and specialized weather equipment should be continued to insure that necessary battlefield observations can be made available to forecasters and other uses (e.g. for clothing and equipment design).

8.312 Equipment

1. Surface observations (temperature, pressure, humidity, wind, clouds, etc.). In addition to presently available surface weather equipment such as fixed, mobile, and packaged weather stations, visibility and illumination meters, cone penetrometers for soil trafficability testing, and devices for measuring river stages, the following equipment should be tested for use in the forward or nearby enemy areas:

a. Back-packed Meteorological Station AN/PMQ-1 and AN/PMQ-4, Naval Aerological Indicator NAX-7-47.

2. Upper air observations (temperature, pressure, humidity, wind, clouds). In addition to presently available upper air weather

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

8-13

equipment carried by balloon or aircraft, the following equipment should be made available for use in forward areas:

- a. Wiresonde Set AN/UMQ-4
- b. Wind Measuring Set AN/MMQ-1 (XE-1)
- c. Temperature-Humidity Measuring Set AN/AMQ-7 for

installation in medium aircraft.

Upper air data from these sources as well as those furnished by meteorological sections attached to artillery units will assist in forecasting artillery ballistics and sound ranging, formation and dissipation of fog and clouds, chemical warfare, anomalous radar propagation, etc. So far as is known very little or none of the data taken by the artillery metro units are made available to the weather forecaster.

3. Radar Weather Observations.

- a. Radar Set AN/CPS-9 and
- b. Radar Set AN/TPQ-6 should both be made available for battlefield use to detect geographical and vertical distribution of precipitation and clouds over the battlefield.

8.313 Communications. A speedy and adequate communications net is required for collection of weather data and charts and dissemination of weather intelligence to the using arms.

8.32 Intermediate (2-4 years)

8.321 Equipment development as follows is under way at SCEL and should be vigorously pursued.

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

8-14

1. Surface Observations.

a. Automatic weather station suitable for installation in sites difficult for access (such as mountains) in our forward areas should be established so that weather data from meteorologically important areas can be obtained.

b. Micrometeorological Set AN/PMQ-2 should be made available, especially for chemical warfare and soil trafficability forecasts.

2. Upper Air Observations.

a. Cloudsonde - to measure height of cloud base and top from ascending balloon.

b. Improved wiresonde set to measure wind in addition to temperature and humidity in first 1,000 feet.

c. Aerograph Set AN/AMQ-6 for measurement and recording temperature, pressure, and humidity along flight paths of high performance aircraft and recording of absolute altitude and winds.

d. Radiosonde AN/AMT-6, an improved parachutesonde to measure temperature, pressure, and humidity between flight level and ground from high performance aircraft.

3. Weather radar, light-weight, portable, 100-150 mile range should be developed for battlefield use.

8.322 Weather Control.

1. Cloud and fog dissipation research should be intensified so that sound operating criteria can be established and climatic

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

8-15

studies prepared to show where in the world and in what seasons such dissipation is possible.

2. Thunderstorm modification research should also be pursued vigorously.

8.33 Future (4-8 years)

8.331 Equipment development as follows now going on at SCEL should be continued.

1. Autosonde - automatic measurement of upper air temperature, pressure and humidity.

2. Coptersonde - measurement of temperature, humidity, and winds below flight level of a helicopter to the ground.

3. Transosonde - for vertical soundings from flight level of a carrier constant level balloon to the ground.

4. Light aircraft weather equipment for observing upper air temperature, pressure, and humidity over nearby enemy territory.

8.332 Atmospheric Detection of Enemy

1. Research in Navy and General Electric to detect enemy vehicles by ionization or nuclei measurements of the exhaust gas.

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

CHAPTER 9

VEHICLES

9.1 Introduction

It is believed that a sufficient pool of vehicle types now exists either in the idea, development, or operational stage, so that adaptation of these types to specific Army reconnaissance requirements could be readily effected, particularly for short time period availability. With a clearer view of the military requirements for sensing system loads and tactical conditions, as Project TEOTA progresses, it might be necessary to undertake the development of a few new vehicles. One such indicated vehicle is the piloted, vertical rising airplane.

The final selection of vehicles to meet the military reconnaissance requirements must be deferred until it is possible to specify the load requirements, such as weight, range, speed, type of equipment, required operating conditions, etc.

This chapter is written in a manner which seeks to anticipate some typical requirements, and then classifies and catalogues the various vehicle types which might match the requirements within the desired time periods. It is thus useful as a preliminary method of approach to vehicle selection, and should be continuously modified as the TEOTA systems program develops tangible form.

9.2 Factors Affecting the Choice of Vehicles

The following significant parameters were selected as representative of preliminary vehicle requirements. These requirements are expressed in two categories of Vehicle Requirements. Vehicle Vulnerability

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

is isolated as an especially important factor in final evaluation.

9.21 Vehicle Requirements. Two important requirements exist. These are:

Type A. Those technical capabilities represented by performance.

Type B. Those representing other operational conditions which are less tangible and not numerically expressed.

9.211 Type A Requirement for Vehicles. Vehicle types which approximately meet these requirements are listed in Tables II - XII, where in the following important parameters are expressed:

Operating Radius, Nautical miles: 2, 20, 200

Velocity Groups, (0-150) (200-600) (700-1100) knots for air vehicles

(40) (60) (80) m.p.h. for land vehicles

Equipment Payloads 50, 500, 1500 lbs.

Control Methods - Piloted and Guided

Time Periods (1952-54) (1954-56) (1956 plus)

Availability Status - Military Prototype

Operating radius is 1/3 range for returnable vehicles, full range for expendable vehicles.

9.212 Type B requirements for Vehicles. The following items are listed as being necessary for future considerations in final selection and operational evaluation, but are not discussed at this time.

Accuracy required

Vulnerability

Expendability

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

Cost

Mission flexibility

Numbers required

Frequency of missions

Level of operational training required

Logistics problems

All-weather characteristics

From a purely technical standpoint the selection of an air vehicle, whether it be a fixed wing, rotary wing, guided or manned, is largely conditioned by the following broad requirements.

What are the characteristics of the load it is to carry?

What range, speed and altitude performance is desired?

What accuracy and flexibility of guidance is desired?

What is the operating environment?

It is only after these requirements have been stated that the secondary considerations of type of airframe, propulsion system, launching system, control and guidance systems, recovery system, defense methods, etc. can be brought into perspective and properly evaluated so that a well-balanced vehicle results.

Technical compromise of component performance is the inevitable result, and if a well-stated basic military objective is available, a good design may generally be achieved.

9.22 Vehicle Vulnerability. One of the important considerations in selection of a particular vehicle out of a group of "possibles" is that

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

9-4

of vulnerability. The currently accepted concept, especially for conditions under aimed weapon fire, is that the smallest and fastest vehicle is the least vulnerable. There are many extenuating factors which may modify this conclusion in degree, but it is generally applicable.

Under conditions of guided weapons fire, the size effect, because seeker system react to target size, probably trends in the same direction. The advantage of speed, however, is somewhat dubious. The reason for this is that missile speeds greater than the vehicle speeds are usually available.

9.221 Detectability. Closely allied with vulnerability is the factor of detectability. Detectability must be assessed in terms of the tactics which will be used, the operating environment, and the enemy detection capability such as type of equipment (radar, infrared), the amount, and density of such equipment.

The above conclusions being qualitative are expressed in words which have many shadings. Since the method of opinions is most unsatisfactory for rational evaluation, it is proposed to use a form of quantitative index to aid decision in making choices of vehicles. This index is the concept of vulnerable area, and there are computation methods available for expression of this factor. A numerical index of detectability should also be developed.

9.222 Size Effect - Vulnerable Area. The generalized form of expression is as follows:

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

$$A_v = A_p \times P_{kc}$$

A_v = Vulnerable area

A_p = Presented area of vulnerable components in the vehicle

P_{kc} = Conditional kill probability of a particular type of weapon

The presented area A_p is usually a fraction of the actual profile area of the vehicle so that the vehicle size alone is not the only factor; it depends on the type of weapon, the type of structure, and the vulnerability of the different equipments within the airframe envelope. It is proposed that such an index, calculated for different anticipated weapons, can supply a useful quantitative value for aiding selection of military vehicles by comparative means.

9.223 Velocity Effect. It is cautioned that A_v does not express the dependence of vehicle velocity on vulnerability. Velocity is one of the components in the hit capability of a weapon. Hit capability is primarily dependent on the accuracy of aim, the tracking errors, the fire dispersion patterns, range, number of guns, etc. By expression of these factors the effects of vehicle velocity can be rationally expressed.

The size and velocity effects take the form of a kill probability in which vulnerable area and hit probability are combined to yield a more refined index. Such a combined form is a more refined expression of vulnerability. However, since the first component A_v , (vulnerable area) has some independent value as an aid to judgment, it is recommended

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

that a start be made by including it as one of the parameters in assessment of vehicles.

9.224 Altitude Effect. Altitude appears to have a generally favorable effect on vulnerability for reconnaissance aircraft in the extreme high and low bands. A small moderately fast (several hundred knots) aircraft hedge-hopping over hilly country at a few hundred feet is an extremely difficult target; also a vehicle at 60,000 feet is hard to find and reach. Vulnerability between these limits should be evaluated.

9.3 Promising Vehicle Types

The following vehicle types appear to have possible application to the Army reconnaissance problem. The discussions are of a preliminary and general nature, as time did not allow detail examination. Thus, this discussion serves only as a first step in the selection process. Additional performance characteristics of most of the following vehicles may be found in TEOTA Memorandums 21 thru 24 and Tables II to XIV.

9.31 Vertical Rising Aircraft. One of the most promising types of future fixed wing aircraft is the piloted high performance vertical take-off airplane. This type of aircraft represents a significant technical advance in the art of air transportation and its military implications are not yet realized. It is especially important to the Army as it does not demand the usual runway facilities with their construction difficulties and vulnerability to atomic attack. A vertical riser pro-

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

gram offers both dispersion of airfields and high combat availability, and it should be investigated by the Army for adaptation of the vehicle to both reconnaissance and tactical combat use.¹

9.32 Fighter Type - Reconnaissance Airplanes. Due to the lack of specialized reconnaissance vehicle requirements, both the Air Force and the Navy have converted operational jet fighters into reconnaissance vehicles. Such airplanes would generally be based about a hundred miles back of the battle line and therefore would require combat radii of about 300 miles to meet the 200 mile reconnaissance radius requirement. Such aircraft as the RF84-F will carry loads of 1500-2000 lbs. while the F2H-2P and F9F-6P will carry 500-600 lbs. Speeds are about 500 knots, and they all meet the required combat radius. These aircraft could be available in the 1952-54 time period.

9.33 Airborne Relay Station. An airborne station which can relay high frequency radio transmission, control low altitude aircraft, and generally overcome the line-of-sight limits of ground antennae, is indicated. A high altitude 60,000 - 70,000 ft. version of such a vehicle could also meet the zone surveillance mission for area targets. Characteristics of two possible vehicles are indicated for further study.

a. A fixed wing airplane which could remain on station several hours at 60,000 ft. appears feasible in the 1954-56 period. A study on the possible modification of the Canberra bomber for such high altitude capabilities has been made by English Electric Company. With vigorous

1. See proposal contained in TEOTA Memorandum No. 24.

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

9-8

application of a development program such an aircraft might be made available in the 1954-56 period.

b. Large balloons launched so that they drift over the combat zone offer a partial solution as a secondary vehicle. The balloons lack primary all-weather dependability, but may have utility in limited situations. A possible balloon would be about 125 ft. in diameter, require 50,000 cu.ft. of hydrogen, and cost about \$2,500.² Although its trajectory would depend on latitude, season, and local weather conditions, it is probable that, in northern latitudes in summer a free balloon would drift very slowly and could even be made to hover several days under some conditions.

c. The Navy Airborne Early Warning (AEW) and Airborne Combat Information Center (CIC) developments should be reviewed for possible adaptation.³

9.34 Small Liaison Airplane. The L-19 airplane even though of low performance has demonstrated a high degree of invulnerability to ground fire in Korea. Fast fighters have also proved ineffective against these low flying aircraft. It is rumored, but not checked, that Russia might be designing a counter L-19 fighter. If this preliminary indication is verified, a study leading to a new reconnaissance type is needed.⁴ A suggested study approach to this problem is as follows:

2. TEOTA Memorandum No. 21.
3. Refer to Project Overhead, Special Devices Center, ONR.
4. TEOTA Memorandum No. 24.

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

9-9

- a. Review and restate L-19 performance and vulnerability to give a base line.
- b. Make preliminary design studies of a family of counter L-19 fighters.
- c. Design an advanced Reconnaissance aircraft to be able to evade.
- d. If study indicates practicability, set a requirement and start prototype development for a new type.

A series of paper studies of small aircraft in this general category is also being conducted for the USAF by Cornell Aero Laboratory.

9.35 Small Drone Helicopter - Short Range. The helicopter has a high all-weather utility to ground forces operations. It is also assumed to be a vulnerable aircraft when exposed to ground fire. Many uses appear for a small, semi-expendable, short range, drone helicopter which can serve as a platform for reconnaissance sensing devices which will transmit data back to base. It is desirable to have good platform stability, night flying capability, and good night time security. A development program for the control and guidance system could be started with the existing HTL, HTE or XH26 craft while a specific prototype was being formulated. Considering the present status of development of the helicopter, it is felt that reasonably satisfactory drone control could occur in the 1954-56 period under conditions of vigorous development. Vulnerability of the small helicopter should be studied and compared to the L-19 and possibly competitive target drones.

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

9-10

In the planning for the advance time period, some utility might be found in a small drone type rotorcraft which was recently studied under Project Lacrosse.⁵ This expendable wire controlled vehicle was proposed as an antitank weapon, to carry a shaped charge warhead and be visually guided by a remote operator. The dominant advantage of low speed is to allow direction to a precise hit on a slow moving target by eye, without the use of a computer.

9.36 General Purpose Helicopter. There are many uses for general purpose helicopters in a transport role ancillary to reconnaissance. One of the specific ones is to transport a packaged ground-based guidance system for close support aircraft.⁶ "Beacon" also recommends a helicopter for transporting and maintaining small electric generating plants. U. S. Marine Corps is investigating the adaptability of the flash metascope, to the helicopter as a photo reconnaissance aid.⁷

These missions are typical of many loads which must be transported for ground network equipment in some of the proposed reconnaissance systems. The helicopter requirements should be examined in terms of such transport when the final systems are defined.

A piloted vehicle is indicated here and should be available in the 1952-54 period by modification of the H-19B and H-21B helicopters. Many potential uses of the piloted helicopter are still unexplored. It has been generally expressed that the helicopters tactical capabilities are very poor due to its slow speed and high vulnerability. Since

5. Cornell Aeronautical Laboratory.

6. USMC Project No. 664 NC-062406.

7. USMC Project NC-062419.

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

9-11

present speeds are not a technological limit and since combat vulnerability has not been operationally evaluated, it is felt that the final verdict should be held in abeyance until some comparative evaluation with existing competitive aircraft of the L-19 type is available.

Although comparative vulnerability may be higher than the L-19, the factor of greater combat availability, especially in fluid operations, might outweigh the vulnerability factor. A comparative vulnerability analysis should be undertaken.

9.37 Artillery Shells, Rockets, Bazookas - Short Range. Artillery is an interesting vehicle for further consideration because within its range it has high accuracy compared with other available vehicles. It is always present on the battlefield and it is under the direct command of the battlefield commander. Rockets have the same general characteristics with the exception of accuracy. The unusual characteristics of artillery and rockets as vehicles for battlefield surveillance should be further studied.

9.38 Small Expendable Missile - Short Range. A small, short-range, guided missile, can be developed by converting "sidewinder" XAAM-N-6 or "Omar" XASM-N-6 type missiles to carry a sensing and relay system of about 50 lbs. 2 to 3 miles. Such vehicles weigh about 150 to 175 lbs. and are developed around the 5 in. HPAG rocket.

9.39 Long-Range High Subsonic Missiles. One of the major objectives of long-range surveillance activity is to search for targets which are suspected, but not known definitely to exist. There is much randomness

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

9-12

in this process and since the probability of success of any one sortie is rather low, the process must be repeated again and again to achieve a satisfactory level of effectiveness. The effort demands repetition and continuity, hence, a costly, expendable, missile system does not present a very promising economic justification. The system cost and effectiveness must be compared with piloted vehicles before major program decisions are made. It is believed that vehicle reusability is a dominant requirement.

If the need is demonstrated, a returnable missile which will reach out to the 200-mile limit could be developed by modifying subsonic missiles of the Matador or Regulus class. They are in the 10,000 lb. gross weight group and have payload capabilities of 2000 to 3000 lbs. at speeds of about 550 knots and altitude of 35,000 to 40,000 ft.

Determination of the prototype vehicle feasibility based on modification depends on the payload remaining after developing a suitable recovery system, a control and guidance system, and installing the desired type of sensing equipment. Evaluation must also be made concerning the type of guidance system to be used. Drone control from aircraft would appear to be the first application as such guidance equipment is already available. The Navy is experimenting with Regulus and the F2H2-P as a mother-control aircraft. Whether drone control of a long-range surveillance missile by airplane or an elaborate ground system is justifiable and operationally feasible must be further studied. In ground controlled systems, even though the vehicle range

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

9-13

may be adequate, the control and guidance system range may not be compatible.

9.310 Target Drone Airplanes. There are many possibilities of converting aircraft of the target drone class into reconnaissance vehicles. The target drone development has encountered all of the problems of missile operations in some form or other during its career, and Air Force and Navy agencies have considerable experience on practical guidance systems and vehicles.

Even though the target drone is generally considered to be a "cheap" aircraft, cost must be carefully evaluated in the military application. The trend of increasing cost with increasing speed is aptly illustrated in the following cost figures. This trend is predominantly determined by the speed requirement as target drones are not designed to carry payloads. The usual dependency of speed and load are conveniently isolated here, in contrast to interpretation of raw cost data on piloted, load carrying airplanes. Production cost of a low-speed drone (180 knots) is about \$4,000, a 300-knot vehicle is about \$20,000 while the estimated cost of a fast drone (600 knots) is about \$50,000. The launching, ground control and guidance systems costs are additional.

Returnable drones in the KD-4, -5, -6, and OQ-19 class could be modified to carry about 20-30 lbs. at speeds of about 200 knots and radii of 75-100 miles. Space is at a premium in this class of vehicle as they are not designed to carry payloads. It is possible, however,

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

9-14

to overcome some of the space limit problems, by the use of external stores, a practice quite common in the piloted-aircraft field.

In the low-speed field, drone versions of the old L-5 (100 knot) observation airplane or more modern light aircraft of the Mooney type, (125 knot) could be converted more readily than most target drones. They could handle a 200-lb. payload at radii of about 100-200 miles.

The existing control systems for target drones fall into two classes.

- a. In sight (visual) systems with practical demonstrated control ranges of about 1-2 miles, depending on visibility.
- b. Out of sight systems (radar) with maximum range capability of about 10-12 miles.

Both systems use radio command transmitter and receiver sets which are well developed, the radar search and track equipment, however, is not yet considered satisfactory for operational purposes.

9.311 Weapon Carrying Drones. Another promising type of drone vehicle for early stage application might be found in the Pelican or Bat class of World War II, and the Petrel and Model "H" class vehicles developed by the National Bureau of Standards.

Since these vehicles were originally designed to carry large war-heads, payload space is available, hence the air-frames can be converted to carry reconnaissance loads more readily than the target drones.⁸ Available volume for payload is indicated to be from 5 to 20 cu.ft. for vehicles which can operate in the 200-mile zone, at

8. TEOA Memorandum No. 23.

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

9-15

speeds of 150-500 knots.

Choice of vehicle between light airplane, target drone, or weapon carrying drone, depends on evaluation of the following items: relative cost, ease of conversion, performance, vulnerability, availability of space for sensing loads, availability of control and recovery systems and production capacity.

It appears that a small, useful, drone reconnaissance vehicle could be developed in the 1952-54 period to operate in the battle zone under visual control for radii up to 2 miles. Application and refinement of radar control would extend the radius to 10-15 miles. If a satisfactory control and navigation system is provided, vehicles of the Petrel or NBS "H" class will supply radii of 100-150 miles.

9.312 Balloons. Balloons have a variety of possible applications due to their low cost, simplicity and stealth. However, there are several dominant operational limits of the device, which make it un dependable as a primary all-weather vehicle. The most serious disadvantage is the dependency on wind direction. Even though trajectories may be predicted within $\pm 12\%$ of range under selected meteorological conditions, the direction of wind may be blowing away from the target at the time the balloon is needed. The gas supply problem may be acute for large operations or for balloons which lift payloads of several hundred pounds. Large portable field generators are cumbersome and not generally available. Despite these disadvantages, the balloon may be regarded as a useful secondary vehicle.⁹

9. TEOTA Memorandum No. 21
Also Project TACIT, Univ. of Conn. Final Report, Chapter 14.

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

9-16

9.313 Man as a Vehicle. Man should not be overlooked as a vehicle for front line reconnaissance purposes. His judgment, intelligence, and ability to improvise, are unmatched by the most complex machine. The technological problem is to equip man with better sensing, communicating and interpreting devices.

9.314 Ground Vehicles. If observation is to be made of terrain and enemy position in the front line, the vehicles should be adequately armored, armed, capable of defending themselves against enemy fire. They must also be designed for operation on the usually scrambled terrain encountered in front-line operations. For this purpose, it is believed the track-laying type of vehicle would be most adaptable and satisfactory. A brief summary of possible vehicles in this class is indicated in Tables XII, XIII, XIV.

On account of the rather limited range of a land vehicle, it is believed that the idea of having a communications relay from a land vehicle to an aerial station (helicopter, plane, etc.) and thence to the headquarters station in the rear of the combat zone could work out satisfactorily. Whether such vehicles should be piloted or drone types requires further study.

Due to the presence of considerable dust and smoke, the possibility of poor visibility during adverse weather conditions must be considered.

Heavy Loads. For heavy loads requiring a large vehicle an adaptation could be made using one of the present medium tanks, such as the M-46 now in production. This tank has the advantages of low silhouette,

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

speed, maneuverability, and is armed and armored to resist enemy attack.

Medium Loads. For medium loads and less bulky equipment the T-41 light tank now in production could be adapted for this purpose, and the reasons stated in the above paragraph will apply.

Light Loads. With extremely lightweight, flexible equipment, the Infantry Transporter, T-166, (a lightly armored vehicle) now being developed under Project ONTOS would be the most satisfactory unit to use. Because of the light armor with which this vehicle will be equipped, it will not be able to withstand heavy enemy assault, but could be used for reconnaissance and possible night operation. A drone version is being developed.¹⁰

Amphibious. As far as the amphibious equipment is concerned, the same reasoning applies as above, and it is believed that sensing equipment can be installed without too much difficulty on either the present or the contemplated amphibious landing craft now being used or contemplated for either the transportation of men and equipment or for assault vehicles.

9.4 Vehicle Selection

A series of tables are included below, with some comments for their use, to serve as a general guide to the selection of a vehicle for a given set of requirements.

9.41 Vehicle Cost. A table of approximate, current production

10. Ordnance Project TT2-740G.

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

9-18

costs of military air vehicles of the classes being considered, is compiled here for comparative guidance and estimating purposes only. Sources of this information are scattered and have not been fully coordinated from the standpoint of inflation, complexity, production, etc. Unit cost of all vehicles except rockets is based on production quantities of 500 to 1000 units.

Speed variation is included in the hope that some trends of design speed vs. cost can be shown.

TABLE I
AIR VEHICLE COST

Vehicles	Unit Cost of Air Vehicles - \$/lb. (weight empty) Exclusive of ordnance			
	Max. Velocity Knots			
	0 - 150	200 - 600	700 - 1100	
Helicopters	15 - 20			
Piloted Airplanes	8 - 12	13-15 Prop. Trainers	25-35 Jet Fighters	40-45 (Est.)
Drones	8 - 10	15	30	
Guided Missiles				20 - 35 Large Missiles
Rockets				2 - 3

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

9-19

NOTES:

1. Piloted airplane costs up to 600-knot class are taken from USAF 1949 data approximately adjusted for inflation and numbers produced. Representative rounded values for various types, in lots of 500, are as follows:

<u>Model</u>	<u>\$/lb.</u>	<u>W.E.</u>	<u>V_{max}</u> . (10,000 ft.)
F86A	25.00	10,052	575 k
T28	14.00	5,770	240
T6	15.00	4,077	180
L5	12.00	1,600	110
L13	12.00	2,024	95
L17	8.00	1,843	135

2. Missile costs are estimated from preliminary data of O.R.O. dated September 3, 1952. By Booz, Allen, Hamilton. At production of 500 units, rounded prices are as follows:

Hermes	28.00 \$/lb.
Corporal	19.00 \$/lb.
Nike	35.00 \$/lb.

9.42 Basis of Air Vehicle Selection of Table II - Second Approximation. Having made a first approximation to selection in Tables III - XI and having reviewed and catalogued some of the possible qualifying air vehicles, a second approximation can be made in which new considerations plus additional judgment can be applied. Table II is the result of such a process. It reflects more specific requirements expressed as

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

9-20

Type A, pg.9-1, which are indicated in the table structure, but still suffers from the unavailability of stated military requirements. It is also limited in its consideration of the intangible items under Type B, pg. 9-1, such as vulnerability, expendability, cost, logistics, etc..

The following considerations were used for guidance in this selection. In general, a model number is not meant to imply the unqualified adaptability of the particular model but is meant to indicate the availability of a class of vehicle which has the required characteristic performance.

Overlapping. Some of the piloted vehicles indicated in the smallest load and range category are far from optimum. They are usually too big if their use is to be exclusive to the particular load/range block. A vehicle in a particular block can generally be used in the next lower range or weight block.

Volume of Equipment. The volume of equipment in payload was not considered. This must be checked, especially in the cases of missiles where the assumption was that relatively diffuse loads would fit into space now occupied by dense warheads.

Drones are particularly lacking in space as they are not originally designed to carry loads. Modification may be difficult.

Piloted Aircraft. Piloted aircraft, especially fixed-wing types, are not generally applicable in the 2-mile category, as vehicles for the immediate battle line should be small, numerous, cheap, expendable, and be under control of the small combat unit.

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

9-21

Helicopters. At the present time, there are several proven applications of automatic pilots and stabilizing devices for helicopters.

Remote servo control systems have not been developed to the group's knowledge.

Payload Definition. The following definition is used as a guide for indicating the equipments assumed to constitute payload in the various categories of Tables II - XI.

a. Piloted Aircraft	= Sensing Equipment
b. Piloted Aircraft	= Sensing / Servo System / Auto.
converted to drones	Pilot / Navigation Sys.
c. Drones	= Sensing Equipment
d. Missiles	= Sensing Equipment (usually warhead replacement)

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

9-22

TABLE II
SUMMARY OF SELECTED AIR VEHICLE PROTOTYPES
SECOND APPROXIMATION
Radius - 2 Nautical Miles
1952-54

Payload		0-150 knots	200-600 knots	700-1700 knots
Small (about 50 lbs)	Piloted	Helicopter H-26 Small Jet		
	Guided	Target Drone OQ-19D	Target Drone XQ-2	Ballistic Rocket 5 HPAG
Medium (about 500 lbs)	Piloted			
	Guided	Liaison Airplane L-16B	Drone Missile NBS-H	
Heavy (about 1500 lbs)	Piloted			
	Guided	Loads too costly for slow exposure	Petrel Missile Returnable	

1954-56

Small (about 50 lbs)	Piloted	Small Jet Recon.		
		Helicopter		
	Guided	Small Jet Helicopter H-26	XQ-2 Target Drone Advanced	Wire Guided Rocket
Medium (about 500 lbs)	Piloted			
		H-13 or H-23	NBS-H	
	Guided	Helicopter Radar Guidance	Drone	
Heavy (about 1500 lbs)	Piloted			
	Guided		Petrel Missile Returnable	

1956

Small (about 50 lbs)	Piloted			
		Small Jet	Lacrosse	Expendable
	Guided	Helicopter	Returnable	Guided Rocket
Medium (about 500 lbs)	Piloted			
		Medium Jet		Jet Drone
	Guided	Helicopter		
Heavy (about 1500 lbs)	Piloted			
	Guided		Advanced Petrel Type Returnable	

Basic trend indicated above is toward Drones and Missiles for short range vehicles over battle line.

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

9-23

TABLE II - (Cont'd)
SUMMARY OF SELECTED AIR VEHICLE PROTOTYPES
SECOND APPROXIMATION
Radius - 20 Nautical Miles
1952-54

Payload		0-150 knots	200-600 knots	700-1700 knots
Small (about 50 lbs)	Piloted	Helicopter H-26		
	Guided	Target Drone OQ-19D	Target Drone XQ-2	Ballistic Rocket
Medium (about 500 lbs)	Piloted	Helicopter H-13 or 23	Trainer T-28A	
	Guided	Airplane L-19 or PQ-14	Drone Missile NBS-H	
Heavy (about 1500 lbs)	Piloted	Helicopter H-19	Fighter RF84F	
	Guided	Trainer T6G	Missile Petrel	

1954-56

Small (about 50 lbs)	Piloted	Convertiplane Bell or McDonnell	Convertiplane Sikorsky	
	Guided	Small Jet Helicopter	Advanced Drone XQ-2 type	Expendable Guided Rocket
Medium (about 500 lbs)	Piloted	Helicopter H-13 or H-23	Append VIII Small Vert riser Piston or Turbines	
	Guided	Helicopter H-13 or H-23	Drone NBS-H	Returnable Missile Bomarc
Heavy (about 1500 lbs)	Piloted	Helicopter H-19	Vert. Riser XFY-1 or XFO-1	Reconn. Fighter F-102
	Guided	Helicopter H-19	RF84F	

1956

Small (about 50 lbs)	Piloted	Convertiplane Bell or McDonnell	Convertiplane	
	Guided	Small Jet Helicopter	Jet Drone	Expendable Guided Rocket
Medium (about 500 lbs)	Piloted	Medium Jet Helicopter	Vert. Rising Rotor Jet (N)	Vert. Riser Fan-Jet
	Guided	Medium Jet Helicopter	Drone	Missile
Heavy (about 1500 lbs)	Piloted	Large Jet Helicopter	Vert. Rising Airplane XFO-1	Fighter 1954 AW-1
	Guided	Surplus Helicopter H-19	XFY-1 Surplus RF84F	

Small piloted aircraft begin to be practical for this radius. Out of sight guidance is required. All slow aircraft trend to rotary wing if available.

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

9-24
TABLE II - (Cont'd)
SUMMARY OF SELECTED AIR VEHICLE PROTOTYPES
SECOND APPROXIMATION
Radius - 200 Nautical Miles
1952-54

PAYLOAD		0-150 knots	200-600 knots	700-1700 knots
Small (about 50 lbs)	Piloted	Helicopter H-23		
	Guided	Liaison Airplane L-19	Target Drone KD6G-1	Sounding Rocket NAX-12-47
Medium (about 500 lbs)	Piloted	Helicopter H-21	Reconn. Fighter F9F-6P	Fighter F-100-A
	Guided	Drone L-19	Drone Missile Recoverable X-10	
Heavy (about 1500 lbs)	Piloted	Helicopter H-19	Reconn. Fighter RF84F	
	Guided	Trainer T6-G	Reconn. Missile Regulus or Matador	

1954-56

Small (about 50 lbs)	Piloted	Convertiplane Bell-McDonnell	Convertiplane Sikorsky	
	Guided	Drone NBS Jr.		
Medium (about 500 lbs)	Piloted	Helicopter H-21		Reconn. Fighter F-101A
	Guided	Helicopter H-21		Guided Missile One way Bomarc
Heavy (about 1500 lbs)	Piloted	Helicopter H-19	Vert. Riser XFY-1, XFO-1	Reconn. Fighter F102-A
	Guided	Helicopter H-19	Missile Matador Regulus	

1956

Small (about 50 lbs)	Piloted	Convertiplane Bell-McDonnell	Small Vert. Riser Turbine Rotor	Small Vert. Riser FAN Jet
	Guided	Convertiplane Bell-McDonnell		
Medium (about 500 lbs)	Piloted	Medium Turbine Helicopter	Vertically Rising Airplane Rotor Jet	Vertical Riser FAN Jet
	Guided			
Heavy (about 1500 lbs)	Piloted	Large Turbine Helicopter	Vertically Rising XFO-1: XFY-1	Fighter
	Guided		Advanced Matador- Regulus	

A good guidance system not limited by line of sight is necessary for drones and missiles.

SECRET
SECURITY INFORMATION

9-25

TABLE III
POSSIBLE AIR VEHICLE PROTOTYPES

FIRST APPROXIMATION

1952 - 1954

- Note: 1. Model numbers merely indicate types which would approximately meet performance and payload.
 2. Adaptability to volume of equipment, etc. must be investigated.
 3. Assumption - guided helicopters not available.
 4. Piloted aircraft generally not economical for such short ranges if this is the only mission.
 5. Drones assumed to have "in sight" control.

Combat Radius - 2 nautical miles

MILITARY PAYLOAD	GUIDANCE	LOW VELOCITY 0 - 150 knots	MEDIUM VELOCITY 200 - 600 knots	HIGH VELOCITY 700 - 1700 knots
Small (about 50 pounds)	Piloted	Helicopter H-26		
	Guided	Target Drone OQ-10D (In sight control) Small Balloon (Semi-Guided)	Target Drone XQ-2 (In sight control) Guided Missile Lark Lisle Gun	Ballistic Rocket 5" HPAQ Omar Guided Missile (Expendable) Sidewinder Sparrow
Medium (about 500 pounds)	Piloted	Helicopter H-23 H-13 L-168 L-19 L-5 L-13		
Heavy (about 1500 pounds)	Guided	Drone Light (Mooney) Airplane Medium Balloon L-168 (Semi-Guided) Drone Trainer L-19 Airplane	Drone NES-H	
	Piloted	Helicopter H-19 Trainer Airplane T28-A Drone Trainer Airplane	Guided Missile (BAT) (Petrel)	
	Guided		Guided Missile (Petrel)	

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

9-26

TABLE IV
POSSIBLE AIR VEHICLE PROTOTYPES
FIRST APPROXIMATION
1952 - 1954

Combat Radius - 20 nautical miles

- Note: 1. Model numbers merely indicate types which would approximately meet performance and payload. Adaptability to volume of equipment, etc. must be investigated.
2. Drones assumed to have "out of sight" control.
3. Guided helicopters not available.

MILITARY PAYLOAD	GUIDANCE	LOW VELOCITY 0 - 150 knots	MEDIUM VELOCITY 200 - 600 knots	HIGH VELOCITY 700 - 1700 knots
Small (about 50 pounds)	Piloted	Helicopter H-26		
		Liaison Airplane L-168 L-13 L-5		
	Guided	Small Balloon	Target Drone XQ-2	Ballistic Rocket
Medium (about 500 pounds)	Piloted	Weapon Drone NBS-H-Jr.	(Out of sight control) KD4G-1	Artillery Shell
		Target Drone OQ-19D (Out of sight control) Drone Airplane L-168	Guided Missile (Lark) (Expendable)	Guided Missile
		Liaison Airplane L-13 L-19 H-23 H-13		
	Guided	Trainer YT-34	Trainer T-28A	
		Liaison Airplane L-19, L-16B L-5 L-13 Light Airplane (Mooney) FQ-14 Medium Balloon (Semi-Guided) Drone Trainer Airplane YT-34	Drone Missile NBS-H Guided Missile (Petrel) Drone Trainer T-28A	

SECRET
SECURITY INFORMATION

SECRET

SECURITY INFORMATION

9-27

TABLE IV (cont'd.)

POSSIBLE AIR VEHICLE PROTOTYPES

FIRST APPROXIMATION

1952 - 1954

Combat Radius - 20 nautical miles

MILITARY PAYLOAD	GUIDANCE	LOW VELOCITY 0 - 150 knots	MEDIUM VELOCITY 200 - 600 knots	HIGH VELOCITY 700 - 1700 knots
Heavy (about 1500 pounds)	Piloted	Helicopter Trainer Airplane H-19 T-28A	Fighter RF84F	
	Guided	Drone Trainer Airplane T6-G T-28A	Guided Missile (Petrrel)	

SECRET

SECURITY INFORMATION

SECRET
SECURITY INFORMATION

TABLE V
POSSIBLE AIR VEHICLE PROTOTYPES
FIRST APPROXIMATION
1952 - 1954

Combat Radius - 200 nautical miles

- Note: 1. Model numbers merely indicate types which would approximately meet performance and payload.
Adaptability to volume of equipment, etc. must be investigated.
2. Guided helicopters not available.

MILITARY PAYLOAD	GUIDANCE	LOW VELOCITY 0 - 150 knots	MEDIUM VELOCITY 200 - 600 knots	HIGH VELOCITY 700 - 1700 knots
Small (about 50 pounds)	Piloted	Helicopter H-23 L-21		
		Liaison Airplane L-13 L-5		
	Guided	Balloon (Semi-Guided) L-19 Liaison Airplane L-13B	Drone KD6G-1	Sounding Rocket ARROBEE (Expendable)
Medium (about 500 pounds)	Piloted	Helicopter H-21	Trainer T-28A (slow)	Fighter F 100A
		Liaison Airplane L-13B LG-126	Fighter Type F9F-6P Airplane F2H-2P (fast) RF-80	
	Guided	Balloon (Semi-Guided) L-13B L-19 Drone Light Air-Mooney plane (Expendable)	Trainer T-28A (slow) Guided Missile X-10 (Recoverable)	
Heavy (about 1500 pounds)	Piloted	Trainer Airplane YT-34 Helicopter H-19	Fighter Type RF8AF Airplane	
		Trainer Airplane T-28A		
	Guided	Trainer Airplane T6-G T-28A	Drone Missile Regulus (Recoverable) Matador F2H-2P is command aircraft for Regulus	

SECRET
SECURITY INFORMATION

9-29

TABLE VI
POSSIBLE AIR VEHICLE PROTOTYPES
FIRST APPROXIMATION
1954 - 1956

Combat Radius - 2 nautical miles

- Note: 1. Model numbers merely indicate types which would approximately meet performance and payload. Adaptability to volume of equipment, etc. must be investigated.
2. Piloted Aircraft generally not economical for such short ranges if this is the only mission.
3. New assumption - helicopters can be guided.

MILITARY PAYLOAD	GUIDANCE	LOW VELOCITY 0 - 150 knots	MEDIUM VELOCITY 200 - 600 knots	HIGH VELOCITY 700 - 1700 knots
Small (about 50 pounds)	Piloted	Small Jet Helicopter		
		Liaison Airplane L-16B Small Jet Helicopter H-26	Target Drone IQ-2	Rocket - wire guided expendable
	Guided	Target Drone OQ19D	Guided Rocket DART (Wire trailing) Guided Missile Lacrosse (Returnable) Lisle Gun	Guided Missile (Returnable) Omar Sparrow Meteor
Medium (about 500 pounds)	Piloted	Helicopter H-23 H-13 Liaison Airplane L-19 L-16B		
		Helicopter H-13 H-23 Drone Light Airplane Drone Trainer YT-34	Drone NBS-H Guided Missile	
	Guided			
Heavy (about 1500 pounds)	Piloted	Helicopter H-19 Trainer T-28		
	Guided	Helicopter H-19 Trainer	Missile Petrel Type	

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

SECRET

SECURITY INFORMATION

9-30

TABLE VII
POSSIBLE AIR VEHICLE PROTOTYPES
FIRST APPROXIMATION
1954 - 1956

Combat Radius - 20 nautical miles

- Note: 1. Model numbers merely indicate types which would approximately meet performance and payload.
Adaptability to volume of equipment, etc. must be investigated.
2. Assumption - helicopters and subsonic fighters can be guided.

MILITARY PAYLOAD	GUIDANCE	LOW VELOCITY 0 - 150 knots	MEDIUM VELOCITY 200 - 600 knots	HIGH VELOCITY 700 - 1700 knots
Small (about 50 pounds)	Piloted	Small helicopter (new) Convertiplane Bell Liaison McDonnell L-16B	Convertiplane - Sikorsky	
		Small Helicopter (New)	Missile Lacrosse Returnable	Guided Rocket (Expendable)
	Guided	Weapon Drone NBS-H-Jr Target Drone OQ19	Target Drone IQ-2	Missile AEROBEE
Medium (about 500 pounds)	Piloted	Helicopter H-23 Convertiplane Bell Liaison Airplane L-19 YT-34	Convertiplane - Sikorsky Vert. Riser Recon-App. VIII Piston or Turbine	Fighter-Reconn. F-102 Airplane F-100Z
	Guided	Helicopter H-23 Drone Airplane YT-34	Drone Missile Lacrosse Missile (one way)	Guided Missile Bombar Returnable
Heavy (about 1500 pounds)	Piloted	Helicopter H-19 Trainer T-28	Vertical Riser XFO-1 XFY-1 XHRH-1 Fighter-Reconn. F-86 Airplane	Fighter-Reconn. F-102 Airplane
		Helicopter H-19 Trainer T-28	Drone Fighter Reconnaissance Missile Petrel	

SECRET

SECURITY INFORMATION

TABLE VIII
POSSIBLE AIR VEHICLE PROTOTYPES
FIRST APPROXIMATION
1954 - 1956

SECRET
SECURITY INFORMATION

Combat radius - 200 nautical miles

- Note:** 1. Model numbers merely indicate types which would approximately meet performance and payload.
 Adaptability to volume of equipment, etc. must be investigated.
 2. Assumption - helicopters and subsonic fighters can be guided.

MILITARY PAYLOAD	GUIDANCE	LOW VELOCITY 0 - 150 knots	MEDIUM VELOCITY 200 - 600 knots	HIGH VELOCITY 700 - 1700 knots
Small (about 50 pounds)	Piloted	Helicopter	Convertiplane - Sikorsky	
		Convertiplane - Bell Airplane McDonnell		
	Guided	Helicopter		
Medium (about 500 pounds)	Piloted	Target Drone - NBS Jr.	Target Drone	
		Helicopter	Vertical Riser Fighter Trainer Fighter Recon.	XFY-1 XFO-1 T-28 F-86 Fighter-Reconn. F-102 Airplane F-101A
		Airplane		
	Guided	Helicopter	Guided Missile Trainer	Guided Missile Bomarc One way
Heavy (about 1500 pounds)	Piloted	Airplane	Fighter Recon.	F-86
		Helicopter	Fighter Recon.	F-89
		Trainer Airplane	Helicopter	XHRH-1 XFY-1 XFO-1
	Guided	Helicopter	Drone Fighter Reconn. Airplane Missile	F-89 Matador Regulus

SECRET

SECURITY INFORMATION

SECRET**SECURITY INFORMATION**

9-32

TABLE II
POSSIBLE AIR VEHICLE PROTOTYPES
FIRST APPROXIMATION
 1956 - -

Combat Radius - 2 nautical miles

Note: 1. Model numbers merely indicate types which would approximately meet performance and payload. Adaptability to volume of equipment, etc. must be investigated. if this is the only mission.

2. Piloted Aircraft generally not economical for such short ranges

MILITARY PAYLOAD	GUIDANCE	LOW VELOCITY 0 - 150 knots	MEDIUM VELOCITY 200 - 600 knots	HIGH VELOCITY 700 - 1700 knots
Small (about 50 pounds)	Piloted	Small Jet Helicopter	Small Vertical riser - Jet-driven rotor	
		Small convertiplane		
		Small airplane		
Medium (about 500 pounds)	Guided	Piloted types questionable - cost	Small vertical riser	Expendable rocket
		Any of the above could be guided - (least certainty for convertiplane)	Guided rocket	Lisle Gun
			Lisle Gun Returnable missile Target Drone	Guided Missile - Returnable
Heavy (about 1500 pounds)	Piloted	Piloted types marginal on basis of cost		
	Guided	Many types possible - small range will demand special types		
	Piloted	Piloted types impractical on basis of cost - both vehicle and sensing load cost		
	Guided	Returnable drone or missile of Petrel type. Cost?		

SECRET**SECURITY INFORMATION**

SECRET

SECURITY INFORMATION

9-33

TABLE X
POSSIBLE AIR VEHICLE PROTOTYPES
FIRST APPROXIMATION

1956 - -

Combat Radius - 20 nautical miles

- Note: 1. Model numbers merely indicate types which would approximately meet performance and payload. Adaptability to volume of equipment, etc. must be investigated.
2. Assumption - helicopters can be guided
3. Airplane, drone conversions, replaced by special purpose drones. Reconnaissance and attack capability.

MILITARY PAYLOAD	GUIDANCE	LOW VELOCITY 0 - 150 knots	MEDIUM VELOCITY 200 - 600 knots	HIGH VELOCITY 700 - 1700 knots
Small (about 50 pounds)	Piloted	Convertiplane Bell McDonnell	Convertiplane - Sikorsky	
	Guided	Small Jet Helicopter	Jet Drone New	Expendable Guided Rocket
Medium (about 500 pounds)	Piloted	Medium Jet Helicopters Airplanes	Vertical Risers New Type Jet Rotor Airplanes Convertiplane	Vertical Riser - New type Airplane - Fan Jet
	Guided	Medium Jet Helicopters Drones	Vertical Riser Airplanes Missiles - NBS - H Convertiplanes	Missiles Vertical Riser - Fan Jet Airplanes
Heavy about 1500 pounds)	Piloted	Large Jet Helicopter	Vertical Riser FY-1 FO-1	Interceptor Airplanes
	Guided	Surplus Helicopter H-19	Surplus Airplane RF84-F	

SECRET

SECURITY INFORMATION

9-34

SECRET
SECURITY INFORMATION

TABLE XI
POSSIBLE AIR VEHICLE PROTOTYPES
FIRST APPROXIMATION

1956 - -

Combat Radius - 200 nautical miles

- Note: 1. Model numbers merely indicate types which would approximately meet performance and payload.
Adaptability to volume of equipment, etc. must be investigated.
2. Assumption - subsonic vertical risers can be guided.
3. Airplane drone conversions replaced by special purpose drones, reconnaissance and attack.

MILITARY PAYLOAD	GUIDANCE	LOW VELOCITY 0 - 150 knots	MEDIUM VELOCITY 200 - 600 knots	HIGH VELOCITY 700 - 1700 knots
Small (about 50 pounds)	Piloted	Convertiplane Bell Helicopter McDonnell Airplane	Small Vertical Riser - Turbine - rotor	Small vertical riser - Fan Jet
	Guided	"		
Medium (about 500 pounds)	Piloted	Convertiplanes Medium Helicopters-Turbine Airplanes	Vertical Riser FY-1 FO-1 Airplanes	Vertical Riser Fan Jet Airplanes F-101-A Missiles
	Guided	Drones Helicopter - Piston	Vertical Risers-Jet Rotor Missiles	Recoverable Missiles
Heavy (about 1500 pounds)	Piloted	Large Helicopter Turbine-Driven	Vertical Risers -Rotor FY-1 FO-1 Airplanes	Fighter Recon. F-102-A Airplane Vertical Riser Fan Jet
	Guided		Missile Advanced class of Matador or Regulus	Recoverable Missile

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

9-35

TABLE XII

POSSIBLE LAND VEHICLES

1952 - - - 1954

Radius up to 150 miles
Speed up to 40 miles per hour

Payload lbs.

50	Piloted	ONTOS Infantry Tracked Vehicle - T-166 105 mm Recoilless Rifle - 1/2" frontal armor - Gross Wt. Approx. 12,000 lbs. 4 lbs. per sq. in. Ground Pressure
	Drone	ONTOS with remote control Ordnance Project #TT2-7400 Same type as above
150	Piloted	T-41 - Tank (light) 76mm Gun - 1" frontal armor - Gross Wt. - 85 tons 9.35 Ground Pressure
	Drone	Above tank can be operated remotely - Aberdeen Proving Ground
1500	Piloted	M-46 (Patton) Medium Tank 90mm Gun - 4" hull armor - Gross Wt. 49 tons
	Drone	M-46 can be remotely operated

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

9-36

TABLE VIII

POSSIBLE LAND VEHICLES

1954 - 1956

Radius up to 200 miles
Speed up to 60 miles per hour

Payload lbs.

50	Piloted	The use of Titanium armor and spaced link tracks can increase the speed and ability of vehicles listed on 1952-1954 chart for increased effectiveness
	Drone	
150	Piloted	
	Drone	
1500	Piloted	
	Drone	
	Piloted	
	Drone	

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

9-37

TABLE XIV

POSSIBLE LAND VEHICLES

1956 plus

Radius up to 200 miles
Speed up to 80 miles per hour

Payload lbs.

50	Piloted	
	Drone	Development of gas turbine engines - all
150	Piloted	electric controls and drive will change this picture from previous analyses.
	Drone	
1500	Piloted	
	Drone	

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

9-38

9.5 Conclusions

9.51 Since the characteristics of sensing equipments and the possible military applications to specific tactical situations have not been defined, the choice of vehicles to carry these loads is extremely fluid. The matching of vehicles, loads, technical requirements, and military requirements is a cut and try process which requires time and continuity of effort.

In view of this condition, it is impractical to state firm conclusions at this time. Instead, therefore, an attempt is made to anticipate some typical requirements. This leads to a classification of various vehicles in tabular form so that selection will be expedited at such time as the military requirements and loads are more specifically expressed. These summaries appear in Tables II - XI for air vehicles, Tables XII - XIV for land vehicles.

9.52 Satisfactory vehicles for most of the requirements of the short and medium time periods considered can be developed by modification of existing prototypes and operational models. Selection of the most promising models for such development should be a continuing phase of this investigation.

9.53 Development of new air vehicle prototypes requires from 1 to 4 years, depending on complexity, so that specialized new vehicles cannot be expected until the late 1954, early 1956 period. This statement is based on the supposition that there will be about a year's lag in formulating a precise requirement and letting a contract for such a new development. Selection of promising new ideas for further prototype

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

9-39

study should be a separate and continued activity.

9.54 Vehicles of the land type using the items listed under Table X would require from 1 to 1-1/2 years for the development of the necessary stowing, mounting and attaching of scanning equipment. This time factor is based on the assumption that vehicles presently available will be modified for reconnaissance sensing purposes. Perhaps future developments will indicate the necessity for a specialized vehicle, in which event the program would run at least into the 1954-1956 period.

9.55 It is necessary that not only a technical evaluation of sensing equipment, vehicles, and control systems is required, but that an operational study of the over-all system behavior be made in order to make rational choices of the most promising systems. The inevitable debate which arises on such considerations as expendability, vulnerability, cost, numbers required, data interpretation, time lag, etc., points up the folly of making decisions based only on technological capability of isolated pieces of equipment. It must be cautioned that, in the enthusiasm of championing a particular sensing device, vehicle, or navigation method, there is a tendency to lose sight of the over-all system in which such items are only components. A good system must work all the way from the reconnaissance vehicle take-off to the final action of the countering weapon.

One of the most urgent needs brought to light as a result of this study is the development of a method to aid the formulation of

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

9-40

preliminary military requirements and the selection of specific systems from the vast array of technological "possibles" presented by the various technical groups in this first phase of the TEOTA project.

It is apparent from the study that specific military requirements geared to the array of technical capabilities presented do not generally exist. Preliminary expression of such requirements must therefore be formulated by an anticipation process in order to guide over-all long range planning and avoid the historically long time delays between initiation of prototype gear and final procurement of operationally given systems.

There are several ways of arriving at military requirements when presented with such a problem.

a. Make One of Everything as Quickly as Possible.

Initiate, then evaluate by operational trial, then finally select the "best".

b. Arbitrarily Select the "Best" Available Equipment.

Discard the rest and proceed through trial and final selection as in (a). Many good ideas will be missed.

c. Analyze the "Possibles" and Select the Most Promising System.

Initiate, then continuously evaluate by means of combined systems analysis and operational trial. Final selection will be a result of the two operations.

It is suggested that method (c) is the approach which will produce

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

9-41

the most useful effect for the least expenditure of time and money. Therefore, it is proposed that one of the first actions which should be taken is to set up a permanent full-time Operational Analysis Group to be available to the Chief Signal Officer to aid in long-range planning and evaluation of the TECTA Program.

9.56 The selection of piloted versus guided vehicle systems is dependent not only on human expendability but on how well the mechanized system does the same job. It is cautioned that sentiment may be stronger than reason in this area and that rational studies should be made on the relative effectiveness of human pilot and mechanization when such occasions arise. Some of the important factors which must be evaluated are: the mission, required flexibility of tactical decision, reliability, cost, vulnerability of both vehicle and ground installations, and returnability of vehicle. Dominant consideration (in the piloted case) and whether human reaction time and saturation of pilots ability to perform the required tasks are really limits.

9.57 A concept of battle zone width should be added to the zone of interest of the study to make it a true volume; length (range) width and height. A standard of width might be that occupied by a typical Corps or Army. With such a concept established, the numbers of various types of surveillance units required in a given system to maintain a given level of activity may be quantitatively established by analysis. Such an analysis would aid considerably in setting up standards for comparison of the relative cost and effectiveness of the systems

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

9-42

which will be subject to further study by the TOTA project.

9.58 A study of the lock-on, computer time and tracking rates of various anti-aircraft gun equipments should be made against various aircraft target sizes and speeds. Such a study could shed much light on the problem of vehicle vulnerability to ground fire and the effects of size, speed and altitude.

9.59 The concept of Vulnerable Area should be reviewed and representative values computed for the vehicles under consideration. This index should be considered one of the standard parameters along with size, speed, cost, etc. in the final selection of vehicles. The subject is treated in more detail in Section 9.22.

9.510 The U. S. Marine Corps (Project NC 062418) has a continuing program for development of detection, tracking and locating devices of targets typical to the combat zone operation in amphibious and land operations. The ultimate objectives of the program are:

To develop remote sensing devices so that:

1. Capabilities and limitations of devices may be determined in test.
2. A concept for the employment of the devices may be developed.
3. Fully definitive military characteristics may be stated.

Due to lack of time, this program has not been examined in further detail. However, it is recommended that the over-all program be reviewed for possible application of equipments, and probable military employment of such equipment.

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

9-43

9.511 The "all-weather" requirement needs restatement and definition as applied to different classes of reconnaissance vehicles and equipment. Guided, piloted, expendable, returnable, etc. categories should be defined to aid in final selection.

9.512 It is believed that the high performance, piloted, vertical rising vehicle has such obvious advantage to the Army operation in both reconnaissance and tactical roles, that a vigorous study and development program should be initiated toward specific application of this new capability. A normal "wait and see" attitude toward its development may result in a five to ten year delay in its military application.

9.513 The need for an airborne relay and control station which could be an integral part of several of the possible reconnaissance systems, recurs many times in the TEOTA study. It appears that a real requirement for a vehicle and a modus operandi exists and has enough generality to warrant immediate operational trial. A program could be set up which would use existing aircraft, navigation and control equipment, plus radar reconnaissance and relay equipment to provide preliminary test experience on the basic method of operation and utility of such a system. Both the U. S. Navy and the U. S. Air Force have done a great deal of work in the field of airborne early warning and airborne data relay. Perhaps some of their equipment and methods could be utilized in the reconnaissance development. It is therefore, recommended that such a program be initiated.

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

CHAPTER 10

NAVIGATION, CONTROL AND GUIDANCE

10.1 Introduction

Sensing devices are useful only when brought within range of the region that they are required to explore. The information picked up must be fitted into its context and identified, in order to become useful intelligence. Thus, the actual sensing organs must be mounted on suitable reconnaissance vehicles, and locations of targets found must be accurately determined, in terms suitable for directing subsequent action, at any time and in any weather.

Means used to do these things are subordinate, and should not limit application of preferred sensing methods. Navigation and guidance devices can only be specified clearly, however, in relation to the sensing means and vehicles chosen for use. Until such a choice is made, only rather general conclusions regarding the subordinate devices can be given. To do this, it is assumed that vision-like surveillance methods and unmanned airborne reconnaissance vehicles are of predominant importance.

If the enemy-held landscape could be painted like a football field with standard, clearly numbered lines, readily discernible and immediately displayed by the sensing system used, the problem of locating targets would become very simple. There would then be little difficulty in directing action against targets found there, though allowance would have to be made for terrain relief. This is the ideal toward which to strive. Coordinated action of diverse units is

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

10-2

difficult unless use is made of some form of common coordinate grid as a reference. Relating observed targets to such a grid is of prime importance for effective surveillance.

10.11 Basic Methods of Locating Targets. The basic methods of locating targets are:

- a. Landmarks: Each target is spotted in relation to some prominent terrain features near it, which in turn have known grid coordinates and orientation.
- b. Navigation Aids: Which give continual determination of:

- (1) The location in grid coordinates of each reconnaissance vehicle, and
- (2) The location of each target found with respect to that vehicle, in grid-coordinate increments.

As increasingly detailed surveillance is achieved, the chance of finding a positively identifiable configuration of natural landmarks in the same field of view as a given target lessens. Liberal use of artificial landmarks, positively identified and accurately surveyed into the grid, is therefore necessary to implement method a above. Whether they are bellbuoys, hand lanterns, or radar beacons, the principles governing the use of artificial landmarks are the same. Surveying-in land-marks may be a process indistinguishable from navigation.

Operation b (1), above, is the traditional position-finding function of navigation. Tools used for its accomplishment are usually

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

10-3

physical energy fields, electromagnetic (radio, infrared, or visible light), gravitational, magnetostatic, acoustic, or aerodynamic.

Operation b (2) is likely to be done by the target-sensing apparatus itself, but normally requires as well, that the reconnaissance vehicle carry a stable and accurate directional reference or platform.

10.12 Required Position Determination Accuracy. The accuracy needed in position determination cannot now be specified with much certainty. Atomic weapons, whether delivered by artillery or guided missiles, need to be directed at tactical targets to within a few hundred yards. Guided Missiles thus armed are expensive so that waste is intolerable; they must hit the first time and substantially every time. Ordinary artillery requires, and normally attains, about ten times better accuracy - a few tens of yards. Because of the lower cost, however, it is reasonable to expend a few ordinary rounds for the purpose of sighting in. If the surveillance means permits spotting and reporting of sighting shots, reconnaissance-vehicle navigation means that permit placing the first shot within a few hundred yards may be good enough for directing ordinary as well as atomic artillery. Within the radius of direct infantry action, perhaps 2000 yards, higher accuracy is likely to be needed. Even to bring a high-resolution sensing device to bear with certainty on a given target, navigation accuracy within several hundred yards may be needed. Unfortunately, most crossroads look alike from the air, and gross mistakes can easily result from inaccurate navigation. Preliminary or routine surveillance of large areas, perhaps with wide

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

strip coverage by the sensing device, may in itself require navigation means accurate only to a few thousand yards. Only if such rough coverage definitely fails to reveal any foci of interest, or if plentiful known landmarks are visible, is such coarse navigation adequate for the entire surveillance job.

10.13 Portability. Portability has a great effect on the operational utility of navigational equipment. Heavy, bulky equipment of high precision is of little use to a camera-carrying man or tiny target drone. Light, low-performance equipment is not optimum if a tank or a big, heavy aircraft is the reconnaissance vehicle. Since automatic equipment can be carried where men dare not go, it alone is portable in the fullest sense.

10.14 Equipment Location.

a. Self-contained equipment, entirely within the craft navigated, is normally used in systems working by measurement of naturally existent fields.

b. Ground Aids are usually necessary when using artificially generated fields. These may range from precision ground radars, working on the primary reflection from a reconnaissance craft that carried no cooperating equipment, to simple corner reflectors on the ground, working with complex airborne radar.

Division of equipment between ground and vehicle is an important operational characteristic, but there is no single best answer. Excess size and weight as well as complexity may be more damaging in the

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

10-5

reconnaissance vehicle than on the ground. The possible expendability of reconnaissance vehicles is an important factor, as is the possibility of common use of equipment for multiple purposes, e.g., the common use of airborne equipment for navigation, for fire control, and perhaps for communication, or the common use of ground equipment for navigation and aerial interception. For battlefield surveillance, vehicle-position information outputs must be made available on the ground; this also influences location of equipment.

10.15 Distance Considerations.

a. Needs exist for devices working in the ranges:

- (1) 0 to 1 mile, the radius of the soldier's hand weapons and mortars.
- (2) 1 to 20 miles, the radius of artillery and of immediate action by armor.
- (3) 20 to 200 or more miles, the radius of guided missiles and major ground actions.

It seems highly unlikely that any single device can best meet all of these diverse needs.

b. Limitations on working distance may be imposed by techniques, as by line of sight to ground-based navigation aids. Such limitations must be removed for generally acceptable operation.

10.16 Control. Guidance of reconnaissance vehicles, to place them where they are wanted, adds beside navigation the function of control. Control may be by:

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

10-6

a. Command, when a human observer decides what should be done, and initiates action to do it. Control equipment may be quite distinct from navigation equipment in this case.

b. Programming, when the vehicle automatically follows a predetermined routine. Vehicle, navigation, and control form such a highly integrated whole in this case that the parts cannot well be studied separately.

10.2 Artificial Land Marks

The usefulness of landmarks lying in the territory to be surveyed is well known, and was mentioned briefly in Section 10.1. However, when the area to be surveyed is enemy territory, necessitating a survey from the air above, natural landmarks cannot be counted on for much help. These two facts, the usefulness of landmarks and inadequacy of natural landmarks, force the consideration of how landmarks might be artificially placed and used in enemy territory.

The general idea in using artificial landmarks is to plant an object that can be "seen" by a reconnaissance aircraft which at the same time obtains a map of the terrain in the "seeing" process. In its most familiar form this would be the situation where a photograph would be taken of the ground, with two or more artificial landmarks in the field of view. From the known positions of the landmarks a two dimensional coordinate grid can be superimposed on the photograph. However, the general scheme is not confined to photography; other systems of map making, such as infra-red photography or radar, are to be considered,

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

particularly radar.

Most schemes for mapping from the air provide information in a two coordinate system. However, it is to be realized that complete reconnaissance would include altitude information, and so the location of artificial landmarks should be regarded as a three-dimensional problem. Any assumption that rough terrain, viewed obliquely, lies entirely in one horizontal plane must lead to large errors in interpreting surveillance pictures.

In present aerial photographic mapping practice, called photogrammetry, elevation contours are developed to overcome the above difficulty. Relative positions of details common to overlapping plane maps, as photographed successively from a moving aircraft, are correlated empirically to extend contours from reference points of known elevation. This arduous correlation process is the heart of photogrammetry. It does not work for radar pictures, because the geometry differs from that of photography, but some radar analog is undoubtedly possible. Fully effective use of artificial landmarks would require some practical way of obtaining rapidly results at least roughly similar to those given by photogrammetry.

Three questions must be considered in evaluating any technique employing artificial landmarks, as follows.

- (a) How will the landmark be perceived and identified by the surveying device (observing plane)?
- (b) How will the landmark be delivered to an appropriate

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

location?

(c) How will the coordinates of the landmark be known?

Partial answers to some of these questions can be given in terms of equipment now existing or under development, and other answers must be given speculatively at this time.

10.21 Marker Characteristics. By the term marker is meant the object itself which will operate as artificial landmark. Important characteristics of markers are the following:

(a) Recognizability. The marker must give some sort of unique signal to the observer so that markers will be discernable from natural objects and also from each other. Markers may be of various types, as described below, and may or may not be active sources of radiation. Active or transponder markers can identify themselves by coding, using characteristic frequencies or pulse groups. Recognition of passive types, which generate no unique signal, would be possible by using groups of them, either in different members or in distinct geometrical patterns. This type of coding is easily scrambled by the enemy, since it requires that each marker remain undisturbed.

(b) Size: Small size is important because delivery of the marker would very likely be through the air, by way of missile or by parachute or other means of dropping from an aircraft. Delivery on the ground by helicopter is not to be ruled out, however.

(c) Length of Life: At the present writing it is difficult to say what this life should be, and, in fact, the operational needs could

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

10-9

probably vary quite widely in this respect. In some cases a life of a day or so might be adequate, whereas in a stable battlefield, the marker's usefulness might extend for several weeks.

(d) Security: Self revelation to the enemy of the existence and position of markers should be minimized. To be useful a marker must remain undisturbed, and so it should announce its presence to the enemy as little as possible. This consideration would indicate that passive or transponder type markers would be preferable to one that operates continually.

(e) Ruggedness: For obvious reasons, the marker must be rugged and should preferably be of low cost.

10.22 Marker Types. The present state of the art includes at least two existing devices which could be used as markers, and others which can be suggested.

a. Visual markers could be relatively simple, and do not require detailed discussion. Detection of visual markers would be by eye observation, photography, or television. The visual classification would include active light sources for use at night. However, active sources would be made long lived with difficulty, and would be relatively easily detected.

b. Radar markers should receive particular attention because of the attractive possibilities of radar mapping from the air under all weather conditions. Radar markers fall into two categories:

(1) Passive reflectors, probably of the corner reflector type,

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

can give strong radar reflections.

(2) Transponder markers offer more flexibility by virtue of their ability to return a coded signal. Also, by having them reply on a different frequency, ground return interference from passive natural targets can be eliminated.

In evaluating possible types of radar markers one of the most important considerations is the uniqueness of the signal return. Intense signal returned from the reflector relative to its surroundings, with only moderate sensitivity to orientation, is the unique mark of the corner reflector. Effectiveness of corner reflectors increases with both their linear dimensions (4th power) and radio frequency used (3rd power). Reflector size required for constant signal to clutter ratio is thus nearly proportional to wavelength (3/4th power). Corner reflectors can perhaps be made with a shutter or hinge mechanism, to modulate the returned signal and thereby provide coding for identification. Transponder markers have the disadvantages of relatively great complexity, with the resulting high cost, and of difficulty in making them completely automatic in operation after being dropped from the air. Two transponders of possible use are in existence, the AN/FPN-18 and the AN/PPN-15. The former is long lived, completely automatic and weighs 250 lbs., whereas the latter is short lived, requires manual setting up, and weighs about 25 lbs.

c. Continuous-Wave Radio markers could be used under certain circumstances, with associated direction finding equipment located in

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

10-11

the observation vehicle. They would also be applicable in a passive microwave observation system such as is now beginning to come under consideration in various circles. Since they would continuously emit radiation, such markers would be relatively easily detected by the enemy, but their relative simplicity would permit the use of a large number of them, if "number" is not used as a coding method as suggested under Section 10.21a. Continuous operation would not necessarily mean heavy power drain because the transmitters could have relatively low power; 10 to 30 milliwatts might be sufficient.

d. Infra-Red markers would probably operate either in the near infra-red, or in the relatively far infra-red (13 microns.) For the former, a light source with a filter for removing visible light would be indicated, while for the latter some sort of "stove" could probably be devised which could automatically go into operation, when in place.

e. Audio markers should be included as a possibility. For purposes of secrecy they would probably be supersonic. Obviously the range of such markers would be quite limited, but they might be applicable for close-in navigation, for the man on foot.

f. Seismic markers can be imagined which would excite impulse waves in the ground. The fields of application of seismic markers and audio markers would be similar, but the seismic type might be more applicable to navigation at close range in hilly country, where hills would offer barriers to air transmission of sound.

g. Radioactive or Chemical markers might be useful in special

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

10-12

situations, despite their very short range of detectability.

10.23 Placing and Surveying the Landmarks. Artificial landmarks are being considered here in terms of their possible usefulness in extending a coordinate grid into enemy territory. Therefore, it is necessary to get them into appropriate locations in enemy territory, and also to survey them in, so that their positions are known on a coordinate system which is built up on a base line in friendly territory. Methods of placing landmarks can be classified into two groups, depending on whether or not coordinate information is provided by the placing process. For the problem being considered placement by the air route is the most logical, although for short range systems a land vehicle or man on foot might be used. Obvious airroute methods are the following:

a. Air Drop: Markers can be dropped from an aircraft, with the aid of parachutes or other fall-breaking devices, such as a javelin nose, or a pillow. Assuming vertical fall and known vehicle position at the time of drop, this method could provide two coordinates of the marker position. For most situations vertical fall can not be assumed, and so position would necessarily be determined by a radar survey, either during descent or after, or by treating markers like bombs and computing position of contact with the ground with a bombing computer.

b. Helicopter delivery should be considered for the expensive and delicate transponder-type markers. Possibly a helicopter could be drone operated in such a service, dropping the markers from about a tree

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

10-13

top level.

c. Missiles* Markers can perhaps be delivered in rocket type missiles, or in artillery shells. The differences between these two methods would be in the size of marker that could be delivered, the destructive forces on launching, and accuracy of placement.

Required range from the battle lines will be a factor in influencing the choice of method of delivery. Dropping from an aircraft has no inherent range limitation, other than the range limitation on the aircraft and on the navigational system used to determine the aircraft position at the point of delivery. Field artillery range is limited to about 8 miles from the battle line, while the range for freely expendable rocket-type missiles would be less. Since it is desirable to know accurately the coordinates at the point where the marker lands, artillery-shell delivery would probably be preferable to rockets in the present state of the art. Estimates indicate marker-placement accuracy of the order of $\pm$ 80 yds., at 7.5 miles with an artillery weapon. Although transponders or corner reflectors could be made to fit into an artillery shell, extensive development would be necessary to provide transponders which would survive the launching. Pending such development, self-propelled vehicles must be considered as possible marker carriers.

A study program to assess the utility of artificial landmarks and to determine the best method of placing and surveying in the

*TEOTA Memorandums: No. 4, No. 25

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

10-14

markers is very much in order. In general, it is desirable that marker position be known from the process of placement; otherwise the need for a follow-up survey to determine the marker positions might to a great extent nullify the value of the system. Determination of the elevation coordinate, to prevent it from confusing the results, is difficult. Study of improved ways of obtaining three-dimensional information from surveillance data should be emphasized.

10.3 Aids to Navigation

Navigation aids have long provided a happy hunting ground for inventors, who have come up with a copious catch of cryptic "brand name" systems. The complexity of the resulting mass of ingenious hardware leads to a great deal of confusion. Similarities must be stressed and differences de-emphasized if one is not to get lost in this confusion.

The fundamental fact that navigational position finding is just applied geometry helps greatly in recognizing similarities of seemingly different systems. In the problems of battlefield surveillance, solid geometry is generally required. Only if navigation is confined to sea level, or if accuracy required is low, can one forget the third dimension.

Measurement of a single navigational quantity establishes only a single "surface of position" in space, and three such measurements are needed to locate fully an unknown point, at the intersection of three surfaces. One of these measurements is commonly that of altitude.

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

10-15

Systems may be characterized by the quantities they measure, which may be distances, distance sums, distance differences, or angles. Shapes of surfaces of position given by measuring these quantities are, respectively, spherical, ellipsoidal, hyperboloidal (two sheets), and conical. Detailed study of angle-measuring methods shows that position fixes based on conical surfaces of position are inherently of low accuracy, because they represent a limiting case of distance-difference measurement that involves a highly unfavorable ratio of lever arms.

10.31 Electromagnetic Systems. Electromagnetic systems, often called electronic aids to navigation, are particularly important, because of their flexibility and high accuracy. All operate by measuring signal-travel times, or sums or differences of these. This is a type of physical measurement that can be extremely accurate.

a. Classification of electromagnetic systems is often made on an operational basis, according to whether or not they involve radiation from the vehicle or craft being navigated, and whether or not they are limited by line-of-sight signal propagation. Both divisions may lack force in the present case. If the vehicle is transmitting much data back to base, it matters little whether it also emits for purposes of navigation. If, as is very likely, data transmission requires maintenance of line-of-sight communication, even at the cost of using airborne relay stations, then line-of-sight navigation is also possible. Ground-wave transmission may be useful, also, but reflected

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

10-16

skywave transmission is never accurate enough for pin-point navigation, and must be carefully avoided.

Another operationally useful classification is by the number of cooperating reference stations (commonly on the ground) needed to give a full position fix. Polar-coordinate systems (Table 10-1), using one distance measurement, one angle measurement, and either a second angle or an altitude, needs a reference base at only one point, but this must have accurately known orientation. Distance-measuring systems (Table 10-2) require two bases, without orientation (dual range), and an altitude. Triple-range systems, using three reference stations and requiring no altitude measurement are also feasible. Distance-difference (hyperbolic) systems (Table 10.3) require three (or four) unoriented base stations and an altitude. Direction finding requires two oriented bases (dual angle) and an altitude for a complete fix. The requirement for multiple or oriented reference stations makes airborne navigation relays more costly than communication relays. The requirement that data output be made available on the ground for control of battlefield surveillance also assists in classifying navigation systems, which have more commonly been directed toward providing data in vehicles being navigated.

b. Status of electromagnetic aids finds two highly accurate line-of-sight systems, both of World War II vintage, ready for use in controlling battlefield surveillance. SHORAN, a dual-range pulsed system, is one of these which works well in the 20 to 200 mile region,

SECRET
SECURITY INFORMATION

10-17

TABLE 10.1
POLAR COORDINATE SYSTEMS*
(Radar Tracking Systems)

<u>Equipment</u>	<u>Range</u>	<u>Status</u>	<u>Availability</u>
SCR 584	32,000 yds.	P	
SCR 784	100,000 yds.	D	
M-33			
AN/TPQ-5	20,000 yds.		
Lacrosse			

*See TEOTA Memorandum No. 12

TABLE 10.2
DUAL RANGE SYSTEMS*

<u>Equipment</u>	<u>Range</u>	<u>Status</u>	<u>Availability</u>
Shoran	Line of Sight	P	
High Precision		D	
Shoran APN-84	LOS	D	1954
Shoran Mod II	LOS	D	
SAGA I	LOS	D	
Saga II	LOS	D	
Saga III		D	Stop gap - WW II
Oboe	LOS	idea	
Stroboe		P	
DME			WW II
Micro-H			

*See TEOTA Memorandum No. 9

SECRET
SECURITY INFORMATION

10-18

TABLE 10.3

DISTANCE DIFFERENCE (HYPERBOLIC) SYSTEMS*

<u>Equipment</u>	<u>Range</u>	<u>Status</u>	<u>Availability</u>
Cyclan FPN-14	Long Range	D	
Cytac	IR	D	1955
Decca	IR	P	Use in Great Britain
Digitac ASB-2(XA-1)	LOS		
Gee	LOS		
Lorac	IR	D	In use in Gulf of Mexico
Loran	IR	P	General use over Atlantic Ocean
Marine Corps Amphibious Guidance System		D	
Raydist		D	
Raydux	VLR	D	
VHF Position Fix			
Whyn	LR	D	

*See TECTA Memorandum No. 18

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

10-19

but requires bulky airborne equipment with an operator, and gives rather inconvenient data outputs. A "quick fix" to remove the operator and improve output convenience may be feasible by using an improved SHORAN AN/APN-84, with an existing Straight Line Indicator. SCR-584 or its modification AN/MSQ-1, the other available system, ties up a very large, heavy and costly ground-based tracking radar to navigate one vehicle in polar coordinates in the 1 to 10 mile region; it is not highly accurate at longer ranges. Light airborne transponders may be used to improve the range and the reliability of the MSQ-1 operation. OBOE, another available dual-range, line-of-sight system, ties up two tracking radars to navigate one craft.

Developments toward improving both of the above types of aid are under way. Model II SHORAN (RCA) is to be miniaturized for external carrying by fighter-bombers, is to be fully automatic, and is to contain a simple computer providing convenient output data; the fighter pod will also contain a bombing computer to use these outputs. Other precision distance-measuring developments (SCEL) are AN/PPN-9 and AN/PPN-13. A group of systems called SAGA, which are rather closely related to SHORAN, have been proposed (Cornell Aero Lab.). These differ from SHORAN in that they would provide economical handling of a number of vehicles by time-sharing use of a single, fast, flexible (but complex) digital computer on the ground. The SAGA proposals minimize limitation by line-of-sight operation, and minimize as well auxiliary data-relaying equipment, even though using the centralized computing facility.

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

NAVAHO is a range-measuring development (FTL) that aims to avoid round-trip transmission by using supremely accurate airborne clocks; it is being directed toward very long range use at low frequencies, with relatively low accuracy.

The tracking radar of the M-33 fire-control system (BTL) is well suited to control reconnaissance, is already available, and represents a modernized radar that is smaller, lighter, and more accurate than AN/MSQ-1. Studies looking toward still smaller, ground-based, precision tracking radars are in progress. Optical or infra-red versions are in process, one for guiding the LACROSSE missile (Cornell AL); another is IRRAD (ERDL). The AN/TPQ-5 is a highly specialized tracking radar that is being developed (GE) toward much higher angular accuracy, rather than just toward smallness. An automatic OBOE (Cornell AL) is now under test at Pt. Mugu. Use of track-while-scan attachments, which need be highly accurate in range only, might alleviate the high cost of OBOE, while retaining its extreme geometrical accuracy by permitting use of a single pair of scanning search radars to navigate many vehicles ("STROBOE").

DIGITAC, an automatic successor to the war-time pulsed-hyperbolic GEE system, using modern techniques and having an airborne digital computer to provide convenient data outputs, was begun as part of the AN/ASB-2 Bomb Director, and is now under development as part of the integrated interception system MX 1179 (Hughes). CYTAC, a successor to CYCLAN, is a low-frequency, pulsed, automatic hyperbolic system now

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

10-21

under development (Sperry), which is expected to reject sky-wave interference and give high accuracy on ground-wave signals out to many hundred miles. WHYN, a frequency-modulated low-frequency system under development with the same objective (Sylvania) has been partially tested, but has not yet achieved adequate sky-wave rejection or satisfactory ambiguity resolution. These are all broadcast systems that do not saturate under heavy traffic, and require no emission from aircraft, but do require airborne computers. All low-frequency systems require very large transmitting antennas, so have very poor ground-station trans-
portability.

DECCA, a low-frequency, continuous-wave hyperbolic aid of moderate accuracy, limited in range by sky-wave interference, and now operational throughout Western Europe and the British Isles, is obtainable in England. RAYDIST and LORAC, two closely related, high-frequency, continuous-wave hyperbolic systems using ground waves, are in some use but are still under development (Hastings Instr. Co., Seismograph Service Corp.). Features of both are used in the Marine Corps Amphibious Guidance System. These CW systems indicate position changes with extreme sensitivity, so may be useful even in the region 0 to 1 mile, but require ambiguity-resolving auxiliaries. While the results are known to be highly repeat-
able, the capability of providing absolute accuracy of pin-point order over terrain of varying geology and strong relief (including cities with steel framed buildings) does not seem to have been clearly established for ground-wave systems.

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

TABLE 10.4

DOUBLE ANGLE SYSTEMS*

Equipment

Loop (or Adcock) D.F.
A-N Range
Omni Range
Consol
Souue
POPI
Electronic Missile Acquisition System (EMA)
AZUSA

*See TECTA Memorandum No. 15

Accurate dual-angle systems (Table 10.4) seem to be limited to the EMA suggestion and the direction-finding aspects of the microwave missile-tracking system AZUSA. NAVAGLOBE and CONSOL, truly, long-range dual-angle systems, transmitting directionally at low frequencies, do not offer high accuracy. High-frequency short-range CONSOL, however, might provide a very simple aid for the foot soldier on patrol. Direction-finding systems are sometimes convenient for navigation (and are necessary for radio-intercept surveillance), but in accurate form are very sensitive to site and instrumental imperfections, and in general do not make full use of their internal instrumental accuracy. Those transmitting directionally do not saturate, since they require no transmission from vehicles using them. Hybrid polar systems (Table 10.5), such as the

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

10-23

civil VOR-DME (ORD) system (already operational) and the military AN/URN-3 -- AN/ARM-21 combination (approaching production) are not being developed toward sufficient accuracy to meet many of the needs of battlefield surveillance.

TABLE 10.5

HYBRID NAVIGATIONAL SYSTEMS

<u>Equipment</u>	<u>Range</u>	<u>Status</u>	<u>Availability</u>
Common System VOR (FRN12A & MRN-9)	LOS	D	Evaluation 1952
Common System TVOR	LOS	D	
Common System DME	LOS		
ARN-21/URN-3 Tac. Nav.			
Course Line Computer		D	1954
Pictorial Computer		D	1954
Arma Pictorial Computer		D	
Sperry Pictorial Computer			
Aero Electronics Pictorial Computer			

Really significant data on comparative accuracies of various systems are difficult to obtain. Many detailed improvements to known electromagnetic aids can readily be suggested, but no highly novel ideas were found in this survey.

10.32 Other Aids to Navigation. There are several navigation aids which do not rely on electromagnetic radiation. At the present state of their development the evidence seems to indicate that the electromagnetic systems are the only ones which are accurate enough for the reconnaissance job involving atomic weapon, artillery, or most aerial weapon employment or reconnaissance instruments with small ground area

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

10-24

coverage. However, considering the possible application to wide strip surveillance, and in the interest of completeness as well as a guide for planning of future development, the following outline of non-electromagnetic navigational methods is included. The fact that non-electromagnetic systems are usually self contained and do not rely on radio communication makes them secure, highly resistant to jamming, and independent of propagation anomalies (they need not have line of sight).

a. Celestial Navigation is here classified as (however illogically) non-electromagnetic for historical reasons. Since celestial navigation is a relatively old subject, it can be dismissed with comments about accuracy and certain recent automatic features. Celestial navigation is inherently inaccurate in terms of fix-error distance by the present standards, because arc length on the surface of the earth is determined from an angle measurement and a subsequent multiplication of the angle by the radius of the earth. Errors are likely to be an appreciable fraction of a mile. Reports of recent developments in automatic celestial navigation indicate that there is no inherent difficulty in constructing such a device. Celestial systems must always include dead-reckoning components to carry the vehicle with reasonable accuracy through periods when the sky is not visible.

b. Dead Reckoning will be understood as navigation by computing vehicle position at any time by integration of measurements

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

10-25

made within the vehicle of some differential variable. By virtue of this integration, errors are cumulative and tend to become large. Since reconnaissance flights may be relatively short, some dead reckoning methods perhaps offer the most promise of the non-electromagnetic systems. Dead reckoning is likely to be used as an adjunct to all navigation aids.

All dead reckoning systems involve the determination of length of arc on the surface of the earth. Some of them share with the celestial system the disadvantage of making angle measurements, from gyro systems (including gyro equivalents of the 84 minute pendulum and inertial frames), which angles are then multiplied by the radius of the earth to obtain length of arc. Other systems fall into a second category in which arc lengths are determined directly, by an integration of velocity with respect to the surface of the earth.

(1) The so-called inertial systems of navigation, which depend only on gravity and Newton's laws of motion, use gyro combinations in such a way that ultimately the angle is measured between the vertical at the starting point and the gravity vertical at the point of observation. A typical situation is one in which the vehicle carries a vertical reference fixed in stellar space (the vertical at the starting point maintained by a free-gyro memory) and the local gravity direction (determined by an 84 minute pendulum). Error which is a function of elapsed time, and is due to irreducible gyro drift, limits accuracy on long flights. For short duration flight the gravity vertical error

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

10-26

would be predominant. Another way to use inertial devices is to integrate acceleration twice to obtain displacement. However, as far as accuracy is concerned, this method also relies on angle because linear acceleration has to be distinguished from gravity with the aid of a stable vertical reference, and is angular acceleration multiplied by the earth's radius. Inertial systems are bulky, and their size increases with accuracy. An order-of-magnitude estimate of present accuracies is given by the following:

Estimated accuracy	Time duration	Approximate weight
1/2 to 1 mile	10 hours	2,000 lbs.
5 miles	2 hours	200 lbs.

Since reconnaissance flights may be of less than an hour duration, for 200 mile ranges, the above specifications may not be too unfavorable, although it must be realized that not all of the above errors are cumulative with time. This is to be particularly emphasized where ranges of 20 miles are considered. It would seem that studies should be undertaken, with the need of short range flights as the objective, with strong consideration being given to more accurate stable vertical references.

(2) Velocity integration to determine displacement is one of the more attractive systems for the job at hand. In systems presently available the velocity is quite accurately determined by Doppler radar, and the main source of inaccuracy is error of direction reference, especially heading error. Primary Doppler speed measurements can

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

10-27

be made to the order of 0.2% of range. Present velocity integration systems, designed for long range use, have weights ranging from 100 to 600 lbs. The important velocity integration devices are tabulated in Table 10.6. A development program for short-range velocity integration systems is needed, particularly looking to the improvement of stable platforms for reducing the inaccuracies due to heading error.

(3) Map-matching is a self contained method of navigation that automatically compares a radar map of the terrain below with a previously obtained strip map of the course to be flown.* Experimental ATRAN flights indicate an accuracy of 750 ft. which is independent of range. Available information is inadequate to judge whether much greater accuracy can be expected with further development. Insufficiency of repeatable detail in radar maps may impose an inherent limitation on accuracy, either because small, bright radar targets are often exceedingly sensitive to direction of viewing, or because some terrain is almost featureless in a radar sense. When appraising map-matching as a possible method for reconnaissance navigation, it is important to understand that a preliminary map-making flight navigated by other means is necessary.

c. Magnetic Navigation: The earth's magnetic field is a vector field the characteristics of which can be used for navigation. Measurement of two components of the magnetic field provides the essential information, but identification of the components is possible only if the vertical and heading are known. Since estimated accuracies are

*See TEOTA Memorandum No. 13.

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

10-28

TABLE 10.6

VELOCITY INTEGRATION DEVICES*

<u>Device</u>		<u>Status</u>	<u>Availability</u>
<u>Air Force</u>			
A-1 GPI	Computer		
AN/APA-44	Tracker and Bombing Computer		
AN/APA-58	Tracker and Wind Speed Computer		
AN/APA-95	Navigational Computer for APN-66		
AN/APA-103	Navigational Computer for APN-87		
AN/APN-66	Navigational Radar		D
AN/APN-78	Navigational Radar for Helicopters (HELINAV)		D
AN/APN-79	Fighter Automatic Navigation (FAN)		
AN/APN-81	RF Head for APN-66, APN-82, APN-87		
AN/APN-82	Navigational Radar		
AN/APN-87	Navigational Radar		
	Automatic Navigational Plotting Board		
NAVATAC	Navigational Computer		
<u>Navy</u>			
AN/ARN67	Lightweight ASW Dead Reckoning Tracer		
	AEW Dead Reckoning Tracer		
LGPI	Lightweight Ground Position Indicator		
<u>Army</u>			
M2 Odograph	GPI for Ground Vehicles	D	Refined WWII-M1
	Pathfinder Vehicles	D	

*See TEOTA Memorandum No. 17.

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

measured in tens of miles, it is felt that for the high accuracy demands of the present problem magnetic navigation of aircraft offers little promise.

One other form of magnetic navigation should be mentioned. The suggestion has been made that navigation for the foot soldier at close range could be accomplished by creating an artificial magnetic field with current loops in friendly territory. As far as is known such a system for use by a foot-soldier exists only on paper, although experimental systems for Aircraft guidance at airports by magnetic induction have been tried.

d. Pressure-pattern navigation has been used as a long range system over water. Position is determined by comparing barometric measurements, corrected for absolute (radar) elevation above sea level, with weather information. The possibility of using this system for short-range reconnaissance seems to be very slight.

e. Altimetry is rightfully classed as a navigation aid in this study since precise air navigation is a three dimensional problem. In relay navigation systems extending line of sight over hills, altitude is a major element of data. Altimeters are of two types, either atmospheric pressure actuated and giving altitude with respect to sea level, or operating by radio reflection from the terrain and giving terrain clearance. Radar altimetry is useful for checking barometric altimeter settings over known reference points. A combination of both types of altimeters can be used to map terrain elevation by flying

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

10-30

over the terrain and recording both altitude above sea level and terrain clearance. Aneroid altimeters having instrumental accuracy of 25 feet at sea level, and 50 feet at 10,000 feet, have been available. Weather stratum uncertainties may increase this error considerably at high altitudes. Present FM radar altimeters with range up to 20,000 ft. over sea, have indication accuracies of the order of ± 2 ft. plus or minus 5% of the elevation.

10.33 Auxiliary Devices. Auxiliary devices are needed for effective use of navigation aids. Some of the important auxiliaries are:

a. Stable Platforms are employed to provide directional reference on moving vehicles.* These make possible determination of the direction in which reconnaissance sensing organs, such as radar scanners or television cameras, are aimed. They also assure correct orientation of airborne relay stations, which may carry radar for use in tracking low-flying reconnaissance vehicles. Good stable platforms are, in fact, of vital importance for accurate reconnaissance. Presently available devices, using gravity-erected gyro vertical and magnetic-slaved gyro azimuth, show overall accuracies in flight of perhaps $1/2$ to 1 degree in vertical and 1 to 2 degrees in azimuth.

Other forms, making more sophisticated use of gyroscopes, might be developed quite quickly on the basis of experience gained with inertial guidance (MIT). These offer promise of at least an order of magnitude better accuracy. Limitation to short-duration

*TEOTA Memorandum No. 26

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

10-31

flights might considerably simplify the problem. Artificial ground-based vector fields may offer promise as another source of direction reference.* A roll stabilization system of this type is now under investigation by JHU/APL for the Terrier missile.

b. Maps are employed to provide efficient and readily accessible cataloging of great amounts of reconnaissance data. These are so vital that operation without use of some form of map is hard to conceive, and so are usually taken for granted. Design of battle-field maps to display directly the three-dimensional, slant-range data of distance-measuring or hyperboloidal navigation aids, in addition to providing customary plan-position map data, is probably not feasible. A compromise to best fit the needs that arise from increasing use of modern precision navigation systems remains an important goal for cartographic development.

c. Computing Methods and Devices are essential to adapt navigation aids to their context and use. Existing map data is always a useful base to build on, and new surveillance data must continually be added to maps. Interconversion between map data and quantities measured by the navigating system is, therefore, perpetually necessary. As required navigational accuracy becomes very high, this conversion must become very exact, a condition so far encountered in full force only in the case of SHORAN. Poor formulation of a computing method for predetermining SHORAN parameters in terms of map data has lead to almost crippling waste of computing time in field operation. Recent

*TOETA Memorandum No. 4.

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

10-32

studies (OSURF) have shown how mere revision of form can make an equivalent computation very simple to perform.

For in-flight conversion of new data from navigation aids into conveniently usable form, automatic computers are necessary. In many cases, careful design planning can make these computers very simple, as in the case of the analog data computer of Model II SHORAN or the DECCA Flight Log. In other cases, a complicated but very flexible computer such as DIGITAC is valuable for its general utility. Acceptance of overly complex computers which are used efficiently by time sharing, as proposed in SAGA, may well prove a desirable practice.

10.4 Control

Guidance of reconnaissance vehicles, to place them where they are wanted adds the function of control besides navigation. Programmed and command control systems represent the two basic types considered here.

10.41 Program. Programmed guidance systems are generally too highly integrated to permit separate discussion of their control elements. Missile guidance systems are generally of the programmed type, and there is at present one system (or more) for every missile, with control elements tailored to match the missile and the navigation means.

Concurrent studies of the other elements of a vehicle surveillance system as well as studies leading to the designation of an overall system or systems have not yet been completed. It will be possible to determine the feasibility of a highly integrated guidance system only in

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

terms of the results of these other component and systems studies.

10.42 Command. Command control has been used primarily on target drones. It comprises, in the better systems:

a. Autopilots to execute commands and maintain vehicle stability. These are of a number of almost-standard sorts, modified as needed to suit the vehicle in use. Several generally satisfactory autopilots, such as the A-12, E-6, E-9, F-1, and F-5, are now available, and improved ones are under development. Helicopter versions are not yet fully adequate.

b. Remote control systems to direct the autopilots. Two of these are now available:

(1) A Navy version, modulating standard radio-communication equipments, not limited to line-of-sight, by on-off keying of multiple tone channels, and

(2) An Air Force version, which pulse-time modulates the AN/MSQ-1 tracking radar used for navigation through the MC-696 telemetering coder, to work with the airborne data link and transponder AN/APW-11.

Each sponsor of the above two systems states that his system is highly satisfactory for drone control, even of high performance drones, and that it is normally line-of-sight. The Air Force combination increases the effective level of utilization of an expensive tracking radar. Other remote controls should be readily developable as needs arise. Less advanced command systems dispense with the autopilot, and

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

remotely control the drone craft directly.

10.5 Conclusions

Based on the foregoing discussions, it appears that:

a. The primary navigational job in battlefield reconnaissance is the vitally necessary one of tying targets found to the standard military grid.

b. This may be done either by recognizing landmarks at known grid positions near each target, or by locating the reconnaissance vehicle with some navigation aid, and determining the direction and magnitude of the vector from vehicle to target.

c. Application of very considerable equipment and effort is required by all known methods of handling the navigational and control aspects of the problem of battlefield surveillance, giving rise to problems of supply, reliability, and maintenance.

d. Differing requirements exist for the regions 0-2, 2-20, and 20-200 miles within unfriendly territory, perhaps requiring different solutions.

For the navigational needs, a number of aids are possible. Conclusions regarding various classes of these are presented below.

10.51 Landmarks.

a. Landmarks can be located at will only if artificially placed. Both active and passive markers have peculiar advantages as landmarks; neither can now be ruled out.

b. Placing of markers by artillery offers promise.

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

10-35

- c. Beyond artillery range accurate placement of markers by air drop may prove feasible, but requires precise navigation aids.
- d. Lack of a simple, fast method of photogrammetry is serious.

10.52 Electromagnetic Aids.

- a. Ground-based electromagnetic systems appear to be the only aids to navigation able to provide adequate accuracy for all battle-field surveillance, either now or soon.
- b. Existing high-accuracy electromagnetic aids are of dual-range (SHORAN), or tracking-radar (AN/MSQ-1, M-33) type.
- c. Airborne relays can preserve radio line-of-sight despite rough terrain, but add greatly to overall complexity.
- d. Existing data on accuracy of ground-wave radio propagation is inconclusive. Reflected sky-wave transmission is never accurate enough for pin-point navigation.
- e. Radio silence of vehicle-borne navigational devices will be less important than usual if reconnaissance data is being transmitted to ground anyway.

f. CW hyperbolic systems (RAYDIST, LORAC) show promise at very short range, dual-range search radar (STROBOE) at medium short range, pulsed dual-range (SAGA, SHORAN II) and hyperbolic (DIGITAC) systems at medium long range, and pulsed cycle-matching systems (CYTAC) show promise at very long range.

10.53 Self-Contained and Other Aids.

- a. Self-contained navigation aids are alluring because of

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

10-36

freedom from jamming and unrestricted range, but are only adequate for some aspects of battlefield surveillance because of limited accuracy.

b. Celestial and inertial navigation systems appear to have fundamental accuracy limitations.

c. Among self-contained aids, the Doppler-integration type offers most promise of reaching adequate accuracy in short-range use. This too depends on improved directional references.

d. Magnetic-induction methods might prove useful at very short range.

10.54 Auxiliaries.

a. Accuracy of existing airborne directional references is hardly adequate, but there is hope of a quickly realized marked improvement in such stable platforms. This is of great importance.

b. Computing procedures used with very accurate navigation aids have been undesirably complex, as have corresponding computing mechanisms.

c. Complex computers that can do many jobs on a time-sharing basis, as in SAGA, offer a new approach to some surveillance problems.

10.55 Control.

a. Control with command provisions with its flexibility, is the type suited for most surveillance operations.

b. With present information, provision of command control systems does not appear to pose major problems.

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

10-37

c. Programmed guidance systems are generally too highly integrated to permit discussion of their control elements separately from their other parts at this stage of development of the TEOTA program.

10.6 Recommendations

10.61 1952-1954

a. Use AN/MSQ-1 or M-33 tracking radar and SHORAN to meet respectively immediate navigational needs in medium and long-range regions.

b. Examine the possibility of making available artillery-laid long-lasting flares and radar beacons.

c. Push development of very accurate, small, and light navigation aids for night patrols, operating at ranges less than 2 miles; include initial study of magnetic-induction.

d. Initiate intensive study of ground-wave propagation accuracy over rough and geologically varied terrain also including cities with steel-framed buildings.

e. Initiate development to apply inertial experience to providing small direction reference devices of high accuracy.

f. Examine utility of artificial fields for direction reference.

g. Examine possibility obtaining OBOE accuracy at reduced cost by application of track-while-scan methods.

h. Explore possibilities of multiple use of equipment.

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

10-38

i. Direct effort toward subminiaturization of radar beacons.

j. Study equivalents of photogrammetry for aid in rapid use of artificial landmarks and interpretation of radar pictures.

k. Investigate advisability of modifying M-33 system for control of surveillance.

l. Examine possibility of eliminating airborne SHORAN operator by quickly combining AN/APN-84, packaged-servo-tracker, and existing Straight Line Indicator.

10.62 1954-1956

a. Field test reconnaissance using artillery-laid patterns of landmarks.

b. Re-assess accuracy of Doppler and integrating accelerometer systems, using improved directional references.

c. Re-assess relative accuracy of ground-wave and line-of-sight radio measurements, using new ground-wave data.

10.63 1956-1958

a. Compare by direct test: landmarks, SAGA, SHORAN II, STROBOE, RAYDIST-LORAC, DIGITAC, and CYTAC, as well as newest self-contained systems, to find optimum navigation systems for battlefield reconnaissance.

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

CHAPTER 11

COMMUNICATIONS and DATA TRANSMISSION

11.1 Introduction:

To exploit thoroughly any surveillance system there must be provided an integrated system of adequate, reliable, and secure, communications which will allow a rapid flow of intelligence to various echelons as required. The problem breaks down into two parts, (1) the circuits associated with actual reconnaissance missions, and (2) the circuits associated with the distribution of the reconnaissance data and other information.

(1) This item involves the techniques necessary to carry out the transfer of information for the guidance and control of the vehicles together with the transfer of the intelligence data back to base. It is likely that the capabilities of the vehicles will impose rather severe restrictions on the communication techniques that can be employed. The solution to these problems will require close coordination with the vehicle, guidance, control and reconnaissance activities.

(2) In this item, involving the distribution of reconnaissance data, the intelligence information will presumably be received at various receiving points and should then have a rapid distribution to proper units from these points. This must be a smooth two way flow of information in order that the intelligence gathering points can sort out the desired information. The branches of this network might

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

11-2

extend from higher echelons through the company level to the squad level. The type of information routed to and from each level will vary with the level. The infantry company needs to know what is happening now in its immediate striking zone. The division commander requires, among other things, information over a greater range of distance and time, and so on through the various echelons.

The numerous factors involved clearly indicate the systems approach is needed and a careful study will be required before a suitable overall plan can evolve.

11.2 Systems Considerations

There is no sharp division between the communications circuits for bringing back reconnaissance information and the communication circuits for distributing this information. It is essential, therefore, that both information requirements be incorporated properly in any communications system. Of course, with the development of new reconnaissance systems, the communications systems must be modified to include such new information. A complete communications system must therefore be flexible to meet changing requirements. Toward this end, it appears desirable that it contain a maximum number of interchangeable units which can be assembled in various ways to meet different demands. From purely practical considerations, proper standards must be established to guide actual construction. Due cognizance must, of course, be taken of the Military Communication System Technical Standards, dated 15 June, 1951.

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

It is essential, however, that before any implementation be undertaken of a communications requirement, that a complete systems study be undertaken to establish the basis for such implementation. The first step of the systems study is a determination of the fundamental requirements to be met. This is perhaps the most difficult part of the task and involves knowledge of such things as

- (a) Type of Traffic
- (b) Bandwidth Requirements
- (c) Volume of Traffic
- (d) Promptness Requirements
- (e) Switching and Routing Requirements
- (f) Storage Requirements
- (g) Data Flow in Real Time or Not
- (h) Security Requirements
- (i) Resistance to Jamming
- (j) Flexibility Requirements
- (k) Accuracy Requirements
- (l) Remote and Automatic Control Requirements

These factors will be briefly examined in order to give a clearer picture of the situation.

(a) Type of Traffic. This will be determined largely by the particular reconnaissance, guidance, and control systems used along with supplementary evaluation information which may be generated at one or more points in the system. A substantial investigation associated

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

11-4

with this item concerns the various forms of coding and their relative merits regarding susceptibility to countermeasures, complexity and reliability of equipment, and performance in general. Other traffic flow will consist of commands and evaluated intelligence being distributed to users.

(b) Bandwidth Requirements. This subject is directly related to the type of traffic, coding methods, and whether or not the data flow is in real time. It is expected that voice transmission will be one of the standard forms, but the possibility exists that various forms of data transmission (including teletype printers) may allow a reduction of voice transmission with its many disadvantages.

(c) Volume of Traffic.

(d) Promptness Requirements.

(e) Switching and Routing Requirements. These three items are closely related in any communication system. As much quantitative data as possible are desired in order to generate a suitable system. By volume of traffic is meant the volume distribution with time which will show the nature of the peak traffic loads. Switching and routing facilities are necessarily related to certain delays, and the final switching means will be predicated on the delays that can be tolerated. The ordinary automatic telephone exchange is faced with the solution of these problems and they are analyzed by means of similar traffic studies.

Message Coding of the Western Union variety can be used to

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

reduce the volume of traffic in some cases.

(f) Storage Requirements. These requirements will depend on the communication system adopted. In the case of teletype traffic it may be desirable to use temporary storage such as punched or magnetic tape at a relay center to hold messages during waiting periods for free circuits. Analysis may show the desirability of storing other types of information.

(g) Data Flow in Real Time or Not. This item will be determined to a large extent by the military requirements and also by the natural limitations of the communication circuits. For instance 30 frames per second TV would be an example of data flow in real time whereas the facsimile transmission of a single photograph would not. The communication problems in the two cases are quite different.

(h) Security Requirements. It is quite likely that short term security would be desirable on some of the communication circuits if this can be done without undue complication and excessive weight. The need for security must be established, and if it is, a proper compromise between extent of security and complexity must be reached. It is understood that fairly simple on-line encoding devices are becoming available and these should be considered for the purpose of giving short term security without the inherent delay accompanying more secure cryptography.

(i) Resistance to Jamming. This factor is particularly important in the case of battlefield surveillance because of the continuous

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

11-6

threat of enemy jamming. The relative susceptibilities of various types of coding and modulations to jamming should be thoroughly investigated.

(j) Flexibility Requirements. This item is associated with the set of standards which should be established to simplify the system. In effect this means a maximum of interchangeable building blocks which may be assembled in various ways to achieve all of the desired aims. This concept allows proper growth of the system without confusion. The problem here is to establish the proper standards on which to build. This will involve such things as bandwidth, frequency stability, antennas, lines, switching techniques, coding means, etc.

(k) Accuracy Requirements. These requirements must be established and a study made of their relation to coding means and error checking means studied. Some circuits carrying redundant messages such as facsimile need not have the accuracy that is required for less redundant messages such as teletype.

(l) Remote and Automatic Control Requirements. These will be determined largely by the natural limitations of these techniques and the work of the people in the control and guidance fields. A close coordination between the communication, guidance, and control activities will be necessary for a suitable end result.

The above list is known not to be all inclusive, but it is shown as an example of the type of factors to be considered in a systems study. It is felt that a major improvement in tactical effectiveness

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

could be realized by using only existing facilities and techniques in a properly engineered system. It is also felt that new techniques will be brought in which should result in even greater improvements.

11.3 Communication Techniques

A number of existing communication techniques will now be discussed in the light of the systems requirements, discussed in the foregoing section.

11.31 Vehicle Circuits. It is estimated that various types of vehicles, from the communication point of view, may be used. Included in these are programmed vehicles having no communication circuits of any kind; controlled vehicles having continuous control, guidance, and reconnaissance circuits; and various combinations of these two extremes. For reconnaissance up to 200 miles, it seems that VHF, UHF, and higher frequencies are probably the most satisfactory frequency bands in which to work, since line-of-sight circuits can be provided by means of airborne vehicles. Another reason for favoring these bands is the relatively wide bandwidths to be handled. Data transmission systems are envisaged to carry pictorial information derived from photography, television, infrared, radar, guidance circuits, etc. The HF spectrum does not offer attractive possibilities for this type of service because of limited interference-free bands, extreme case of jamming, and multipath transmission resulting in multiple images and inaccurate guidance information.

A solution to most of the problems of communication comes about

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

if use is made of microwave frequencies with as much antenna directivity as possible at each end of the circuit. This method gives the following advantages:

(a) Freedom from enemy jamming increases in proportion to the amount of antenna directivity used. It is here assumed the reconnaissance vehicle is moving about so that a fixed jammer is at a disadvantage.

(b) A great saving in transmitter power is achieved since the antenna gain at each end of a circuit contributes to the overall gain of that circuit. For example, the use of 30 db antennas gives an overall circuit power gain of 10^6 over the condition of non-directive antennas.

(c) The enormous gain in power from directive antennas allows much smaller and lighter equipment in an airborne vehicle and may spell the difference between success and failure.

(d) The multipath problem is greatly minimized. This is a serious problem in pictorial and guidance transmission giving rise to multiple images and ghosts.

(e) The directive antennas systems when locked on the line-of-sight path automatically supply guidance information if supplemented with range information derived from other techniques.

(f) The directive antenna system is of some help in maintaining privacy of the mission and in preventing enemy monitoring of the communication link.

A serious problem arises in the mounting of directive tracking antennas on the airborne vehicles. This is at present an unsolved

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

problem, and will require the availability of suitable vehicles. It should be a field for future development as the benefits to the communication problem are very great.

The actual choice of frequency will depend on a number of factors which include atmospheric attenuation, rain and fog attenuation, allowable antenna size, transmitter power available, receiver noise figure, and distance to be covered. These factors must be weighed for the various types of circuits. For instance super high frequencies, of the order of 20,000 to 40,000 MC, have severe atmospheric absorption, and could profitably be used for fairly secure short range line-of-sight communication. On the other hand frequencies of the order of 10,000 MC will probably be more satisfactory for circuits up to 200 miles in length because absorption is less, receiver noise figure is better and large antenna gains are physically realizable.** At a frequency of 16,700 MC ($\lambda = 1.8\text{cm}$) it is to be expected that heavy rain would give about 1.6 db less per mile above the normal circuit attenuation. This is of course intolerable for circuits over about 10 miles in length. Light rain and atmospheric absorption would give an attenuation of about 0.11 db per mile above the normal circuit loss. Despite the high heavy rain attenuation it would be expected that such a circuit might be satisfactory up to 100 miles. This example is rather an extreme case to illustrate the higher frequency possibilities. Excessive sizes of antennas

** Radiation Laboratory Series, McGraw Hill, Vol. 13, Chap. 3. Also Beacon Hill Report, 15 June 1952, Project Lincoln, Chap. 9.

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

are probably not necessary with frequencies as low as 10,000 MC, and even here an impressive power gain is realized along with sufficient directivity to maintain considerable freedom from jamming. Rain might be expected to give occasional trouble even at 10,000 MC, but such heavy rain might also deteriorate the surveillance method unless it depends on a lower frequency.

TEOTA Memorandum No. 27 shows some of the basic calculations for microwave circuits without taking into account atmospheric absorption. The purpose of this memorandum is to show some of the natural limitations of this field. It also implies that distances up to 200 miles will not be adequately covered in the microwave band unless directive antennas are used.

The use of directive microwave communication systems with their attendant line of sight range limitation imposes a need for a radio relay using a series of airborne vehicles with continuous two-way communications between the airborne vehicle and its base. A two-drone aircraft system seems to possess the required capabilities, and might operate somewhat as follows: One of these, the mother drone, would fly sufficiently high to be in constant line-of-sight communication with its ground base, via UHF or microwave radio. The other (daughter drone) will fly at any desired altitude below the mother drone. Control of the daughter drone, and communications from the daughter drone, will be relayed via the mother drone.

The mother drone would be equipped with a highly directional

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

11-11

antenna for microwave communication with the daughter drone. This antenna will automatically track the daughter drone. The daughter drone would be "flown" from the ground without reference to the mother drone. The position of the mother drone with respect to the daughter is obtained from the position of the tracking antenna, and transmitted to the base. An operator or computer at the base will "fly" the mother drone in a more or less fixed position relative to the daughter.

For short range reconnaissance the mother drone may not be necessary, and provision should be included to control the daughter drone directly from a ground station, without requiring the relay plane.

The most attractive features of this approach are:

- a. It provides an aerial platform capable of low altitude flight out to large ranges and in constant communication with its base. This platform can support and guide various types of surveillance equipment.
- b. No new invention is required; however improvement of existing techniques is required.
- c. The system has inherent anti-jamming advantages, due to the possibility of using UHF or microwave techniques throughout.
- d. The system lends itself to making the more vulnerable daughter drone the cheaper of the two.

Any system of this type is subject to the experimental limitations

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

11-12

deduced from air-to-air and air-to-ground microwave propagation studies.*

It was found that propagation between two high aircraft suffered from dead spots due to atmospheric stratification. However, the system is feasible if the drones are alternately at high and low altitudes.

Other vehicle techniques employing high altitude balloons or reconnaissance missiles may also find application for long range surveillance.

The possibilities of long range VHF or UHF propagation presumably due to scattering effects of the atmosphere, or ionosphere, should be considered for possible applications to the reconnaissance program.** Experience to date has shown that very large powers are required to cover large distances, but more reasonable values of power may be adequate for ranges under 200 miles. Investigations in this field are being carried out by BTL, CRPL and Collins Radio Company.

11.32 Distribution Circuits. Attention is here directed to the fact that an expanded reconnaissance program such as that envisaged under TEOTA would add considerably to the volume of reconnaissance and other information for proper distribution to a variety of interested headquarters. The present communication system would normally be called upon to handle the added volume of traffic. This might prove to be a serious bottleneck, since without adequate allowance for such an added volume of traffic, the communication channels might not be adequate

*U-21496, Final Report Part III 10 Dec. 1951, Investigation of Air-to-Air and Air-to-Ground Experimental Data, Cornell University, AF33(038)-1091. U-21853, Final Report Part IV, 10 Dec. 1951.

** Project ROAR, Office of the Chief Signal Officer.

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

11-13

to handle the total communication requirements.

A complete systems study of the problem must be made in order to provide adequate communication circuit facilities. This study should include both the vehicle and distribution circuits.

11.33 Short Range Communication. There are many applications of short range communication for tactical reconnaissance. Various worthwhile proposals are discussed in Chapter XII, Telemetering, of the TACIT report by the University of Connecticut for ORD. The appendix to this chapter discloses the characteristics of a number of low power portable, battery operated equipments now existing. Since it will serve no useful purpose to duplicate here any of the TACIT work, the reader is referred to the complete Chapter XII for full details. In passing it is noted that the short range circuits discussed are mainly ground-to-ground although ground-to-air is mentioned. When there is difficulty in having antenna directivity, it is proposed to store information at a detector-transmitter behind enemy lines for transmission at programmed times, with short messages to avoid enemy detection and countermeasures. This principle and other similar ones mentioned are quite sound and also result in battery life greater than that obtained with continuous transmission.

Project VISTA report indicates a pressing need for a short range communication set to be used by front line personnel which will be reliable up to 100 yards and undetectable at one half mile. It is believed that these numbers may be somewhat on the short side, since

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

11-14

this report cites a range requirement of 400 yards based upon tests made in the Pacific during World War II.

The requirements enumerated for a communication set to meet these front line short range communication conditions are as follows:

- (a) Shall be capable of operation on opposite sides of a ridge, in fox holes, in forest or brush, etc.
- (b) Weight of 2 lbs. or less.
- (c) Relatively vibration and shock proof.
- (d) Flashlight battery supply.
- (e) Omnidirection transmission and reception.
- (f) 100 yds. reliable; one half mile undetectable (?)
- (g) Jam resistant.
- (h) Interchangeable with all other units.
- (i) No complicated adjustments.
- (j) The receiver should be capable of D/F on transmitter.
- (k) Transmit and receive simultaneously.

The proposal for a set to meet these requirements in the VISTA report would have the following technical characteristics:

- (a) An induction type of transmitter receiver with the loop antenna worn around the body.
- (b) Frequency range in the 50-100 KC region.
- (c) Use of transistors throughout.

The reader is also referred to the BEACON report, and to the report by Mr. R. S. Holmes to the Signal Corps Advisory Council on communications

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

11-15

relating to the BEACON Mission, for additional information and recommendations concerning the short range communication problem.

TEOTA Memorandum No. 28 reviews the short range communication problem with references to much material of interest. The intent is to list the generally available items required for short distance communication channels even though the requirements for the system are not yet fully established. An important objective of a project such as TEOTA should be to set down the requirements that the system must meet. A second item of importance is to survey and record the known art. The difference between these two delineates the scope of the research and development program.

11.34 Security and Intercept Analysis. The reconnaissance problem in its broader aspects necessarily includes the observance of enemy electromagnetic emissions. It is assumed that the context of any received enemy messages will be processed by the proper authorities. However, aside from the contents of the messages there is considerable information from the reconnaissance viewpoint in the fact that such transmissions are taking place. The location of transmitters, the volume of traffic, types of emission and frequencies are all factors which contribute to the knowledge of the enemy's strength and disposition.

The BEACON Report, July 1952, and the report by Mr. R. S. Holmes to the Signal Corps Advisory Council on communications relating to the BEACON Mission, points out the need for equipment designed specifically for forward area intercept purposes, with suitable intercept and

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

11-16

direction finding features.

This problem is discussed in some detail in the BEACON HILL Report of 15 June 1951 and is being stressed here because it involves communication equipment and techniques. For this reason it is felt that it is a subject for consideration in the systems study. TEOTA Memorandum No. 29 presents a suggestion to furnish the tactical commander close to the front lines with such intelligence in time for it to be of value.

There is a forthcoming report of the Signal Corps Advisory Council, Task Group 5, Security Devices, which is expected to discuss the various aspects of intelligence and security problems. Since this subject is closely related to the communications work, it is suggested that the pertinent recommendations of this report be made available for use toward the solution of the communications problem. It is also expected that this report will point out the need for greater cooperation between ASA and the tactical Army command.

11.4 Data Transmission, State of the Art

This is a subject with which communications study program is vitally concerned. The details are given in TEOTA Memorandum No. 19. An abstract of this work is as follows:

This TEOTA Memo. discusses the problems involved in data transmission from the point of view of both basic communication theory and practical circuits. Data transmission may be divided into two classes, Explicit and Implicit. The former involves the transmission of voltages

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

11-17

or shaft positions proportional to the time variants of interest. The latter involves transmission of a whole field which includes the functions of interest as a portion. An example is video radar PPI transmission. Two important characteristics of explicit data are usually its extremely low frequency range, often from zero to a few cycles per second, and the precision in both magnitude and time with which it must be reproduced at the receiving end. Ordinary communications circuits include noise and other variations of enough magnitude to require the use of bandwidth expansion to materially reduce the effects of these perturbations on the output data. Of the band-width expanding methods, pulse-time modulation and pulse-code modulation lend themselves to time multiplexing of data (which are usually multiple) whereas frequency modulation lends itself more readily to frequency multiplex. Compared with explicit, implicit data transmission generally involves broader bandwidth and lower precision. Approaches to reducing bandwidth are discussed. One approach involves a conversion to explicit form.

Representative data transmission systems are described and their operation related back to basic communication theory. A section is devoted to input and output devices. In general, the simplest data transmission systems are the least accurate and considerable complexity must be tolerated when high accuracy is required. PCM systems represent the most efficient utilization of bandwidth and time for transmitting data signal when a high precision is required. On the other hand PCM systems

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

11-18

involve a high order of equipment complexity. Application of transistors to PCM equipment design will greatly reduce size and weight.

Many data transmission systems incorporate means for parallax correction; one section is devoted to this and to earth-curvature problems. Other aspects discussed are smoothing and prediction, system applications, also special equipment and transmission problems.

The most fruitful lines for accelerated research and development cannot be exactly determined until the job required of the data transmission elements of a system is formulated. Some possibilities are listed below.

1. A study of the various transmission methods and the resistance to jamming.*
2. Research to simplify PCM coders and decoders.
3. Development of field wire with special properties for short range data transmission use.
4. Study of switching methods and components for reliable transmission of short pulses.
5. Research to obtain a high speed switch having a reliable back-to-front resistance ratio of the order of one million.

Many of the foregoing considerations have been studied in considerable detail in the problem of data transmission between an anti-

*Contract DA-36-039Sc 15358 with Engineering Research Institute, Univ. Mich., Ann Arbor.

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

11-19

aircraft operations center and an anti-aircraft gun battery center, which has resulted in the Signal Corps Project 414a. The data transmission equipment which was developed as part of this system is known as the AN/TSQ-1. The technical characteristics of this equipment are available in detail through Signal Corps sources. Its main attribute is its capability of transmitting highly precise positional information on a single aircraft. This equipment suffers amongst other reasons from being too complex and costly. What is required for this application is a relatively cheap, simple, and reliable data transmission equipment which can report on dense aircraft traffic and give all the necessary information on each aircraft such as position, velocity, height, identity, and description if known, etc. Now under development at the Bell Telephone Laboratories under a contract with Coles Signal Laboratory is the AN/TSQ-7 Coordinate Data Set whose characteristics will be designed to satisfy the requirements as noted above. This development has been based upon the joint requirements of the Signal Corps (Anti-aircraft Defense System being developed under Project 414A) and the USAF Rome Air Development Center (Ground Reporting System).

It is noted that the problem within the Zone of Interior is similar to that involved in transferring radar information between different elements of the tactical air radar network and associated field army services, such as the anti-aircraft artillery. Thus despite the fact that the storage for data may be different in separate installations, depending on the end use, there is much to be gained in standardizing

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

11-20

wherever possible on the information code frame or data line signal generated by the AN/TSQ-7. Such standardization would make the data language common and available to all military services who might use such data.

11.5 Recommendations

A number of recommendations are made herein, which are divided into two periods, short time, and long period programs.

11.51 Short Period Programs (2 years)

a. The development of techniques to improve short range communication, short range intercept, and direction finding, as pointed out in the BEACON Report, and the report by Mr. R. S. Holmes on Communications to the Signal Corps Advisory Council.

b. An examination of existing communication equipment to ascertain which might be applicable on an interim basis, either with or without modification, to the various forms of reconnaissance proposed by the various chapters in the TEOA program.

c. Review experiments with placing field wire by aircraft, rocket, gun or mortar fire, and undertake such further tests as may be necessary to determine the feasibility of placing into enemy territory microphones with connecting wires. Advantages may be gained by the use of wire which is designed for this purpose.

d. Measurements and tests should be made of Spiral 4 cable to determine its usefulness in transmitting video signals over short distances. It is noted that a field coaxial cable for longer distances

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

11-21

is under development by the Signal Corps.

e. A study of the radio art to ascertain what equipment could be used for short haul video transmission. A longer range development program might ultimately prove necessary to satisfy the requirements.

f. A study of the various transmission methods, and their resistance to jamming.

11.52 Long Period Program (3-5 years).

a. A comprehensive systems study to integrate the reconnaissance communication requirements with the standard military communications systems wherever possible. As a prerequisite to this study, the reconnaissance communications requirements must be firmly established.

NOTE: It appears evident that in the past a defense system design had a tendency to concentrate on terminal devices, and to take the communications for granted. This tendency overlooks the fact that many of the capabilities and limitations of the overall system are determined by the communications aspects of the system.

It is judged that systems planning should logically be one of the main duties of the Signal Corps Engineering Laboratories. This type of work involves an intimate knowledge of military requirements and a broad knowledge of the state of the various related arts. It is a type of work which is most effectively carried on after a long period of familiarity with the problems and requirements. It is a more or less continuing study, and requires a permanent staff of experts in this

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

11-22

field. Such a permanent staff of experts should be acquired by the Signal Corps, and an organization which provides Joint Service liaison and participation, should be established.

b. This recommendation follows directly from a. With the establishment of definite reconnaissance communication requirements, to provide any new communications equipments specified by the systems planners.

c. Development of a communications intercept and analysis system for battlefield surveillance. This should make use of the fact that radio communication and radar activity of enemy units can serve as a source of information that can supplement other reconnaissance in determining the strength and disposition of enemy forces. To be useful, the information must be available with a minimum delay. One such system is proposed in TECTA Memo. No. 29.

d. Establishment of a program which closely coordinates and integrates the communication requirements with the development of reconnaissance vehicles. Particular attention will be necessary to the development of systems which incorporate tracking, directive, microwave antennas.

e. A study of data transmission systems, with particular reference to:

1. Research to simplify PCM coders and decoders.
2. Study of switching methods and components for reliable transmission of short pulses.
3. Research to obtain a high speed switch having a reliable back front ratio of the order of 10^6 .

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

CHAPTER 12

OTHER METHODS AND PROBLEMS

12.1 Introduction

It is the purpose of this chapter to discuss several technical matters which cannot clearly be placed in the previous technical categories. These include visual techniques, magnetic techniques, and an overall testing program.

12.2 Visual. The human eye is one of the finest sensing devices available, and, as such, the eye has been the primary means of performing military surveillance from time immemorial. Its limitations in range, ability to see at night or under adverse weather conditions, and the inability of the associated brain to store and reproduce precisely have lead to the development of many of the techniques discussed in this report. Generally the present study did not consider the problems associated with use of the eye as a direct sensing device. Thus field glasses and related optical equipment were not studied, excepting those cases in which optical systems are auxiliaries to other sensing devices under consideration. Likewise no review was made of observer training techniques and equipments, either for ground or air application. The so-called "image intensifier", a scheme for using electronic application of images for visual presentation and interpretation is discussed in the chapter on Infrared Devices.

12.21 It is noted that Project TACIT has been concerned with aspects of the use of visual observers. Curves indicating the area of probable direct visual coverage for observers at various elevations in typical

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

12-2

terrain have been computed. These curves allow quantitative estimates of the effectiveness of elevation not only for visual observers, but for any line-of-sight sensing device. As a result of its study Project TACIT is considering the use of portable towers, capable of rapid erection and collapse, as an adjunct to visual observation and as a platform for photographic and sensing devices for front line usage.

12.22 The Beacon Hill Report and the USAF representative to TEOTA indicate the possibility of obtaining considerable reconnaissance benefit by the exploitation of human observers in high speed aircraft.

12.23 Recommendations:

- a. The early field evaluation of Project TACIT tower proposals be undertaken.
- b. The U. S. Air Forces consideration of the capabilities and limitations of human observers in high speed aircraft for ground reconnaissance purposes be endorsed.

12.3 Magnetic Techniques

The earth's magnetic field is subject to distortion by the presence of magnetic materials. This phenomena has been used as the basis of a geophysical survey technique for the location of magnetic ores and of sub-surface structure. It was also used as the basis of the Magnetic Airborne Detector (MAD) used by the Navy during WW II for the location of submarines. The NDRG Report (1946) includes some data on the use of MAD against landborne targets, but the technique has not been exploited for land military purposes.

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

12-3

12.31 The earth's magnetic field is of the order of 60,000 gamma, with considerable variation in magnitude over long distances. The local variations are generally small, the inherent magnetic noise in a quiet location being of the order of 0.5 gamma.

Submarines produce sufficient distortion to be measurable at distances of the order of 1000 ft. Individual military vehicles in convoy were detected at 100 ft. by the Navy WW II airborne equipment. The magnetic distortion produced by vehicles was found to vary as much as a factor of four among vehicles of the same type. Despite their small amplitude the signals from military vehicles were well above the noise and were distinguishable by their sharpness from distortions produced by ordinary terrain variations. While typical MAD records are shown in the NDRC report, no comprehensive information is available on the amplitudes of the magnetic distortions produced by various military equipments.

The sensitivity of the WW II equipment was sufficient to indicate the inherent noise produced by ordinary terrain variations, so that improvements in sensitivity would not appreciably improve the resolving power of this technique. Existing equipment utilizes a mechanically complex servo system to orient the magnetic head in the direction of the magnetic field. This arrangement produces instability and noise during maneuvering of the aircraft and thereby limits the effectiveness of the technique. The Navy has attempted to reduce the maneuvering limitation in the development of new equipments.

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

12-4

The Navy is actively investigating the miniaturization of equipment by use of new developments in circuitry and components. A breadboard model incorporating such advances is underway at Johnsville Air Development Center. The Navy is also supporting research in the magneto-meter field, particularly with respect to the improvement of sensitivity by several orders of magnitude through the use of new magnetic effects. Such a highly sensitive magnetic device might be used in a differential arrangement measuring the difference in the earth's field over a very short space, thereby reducing the effects of terrain noise considerably.

The state of the art is indicated by AN/ASQ-1, WW II equipment. This equipment weighs 135 pounds, with a volume of 3.9 cu. ft., not including the primary power supply which is normally furnished by the aircraft electrical system. The primary power requirement is 8-12 amperes at 24 volts DC. The equipment would produce full scale deflection for changes of the order of 1.0 gamma while flying at speeds of 135 knots.

The AN/ASQ-1 is currently being replaced in the naval service, so models should be available for experimentation. The new equipment, AN/ASQ-8, is under quantity production. Its limitations are generally similar to those of the WW II equipment, with exception of improvement in the maneuvering capacity. The new equipment represents no great saving in weight, or volume. Considerable difficulty is encountered in the compensation of the aircraft upon installation of MAD equipment. Installation of the AN/ASQ-8 has been slow due to the aircraft compensa-

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

12-5

tion problem. Several of the new equipments are operational in blimps at the present time.

12.32 Conclusions.

a. The large masses of iron in mechanized field equipment distort the earth's magnetic field at sufficiently great distances to be measurable by airborne-sensing equipment.

b. The technique is applicable to the location of groups of vehicles, an intelligence requirement of the army division and corps.

c. WW II equipment indicated the rough limitations of this technique but there has been no exploitation for ground surveillance applications.

d. Experimentation and data are required before a decision can be made as to the probable military value of this technique.

e. Employment of this technique will require a vehicle flying at low altitudes. A simple telemetering channel will suffice for transmitting the detection information from the sensing device to a base point, so the remote indication of information should pose no special problems in the application of this technique.

f. The Navy can be expected to continue active research and development in this field, so no large scale Army program is required. However, close liaison with the Navy is desirable as well as active Army trials of the Navy developments.

12.33 Recommendations:

a. That quantitative measurements be made of the magnetic distortions produced by military equipments. This tack requires con-

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

12-6

siderable military equipment and might well be done as a sub-unit of the overall basic task of determining the distortion, radiation, and reflection characteristics of military equipment with respect to all physical phenomena.

b. That consideration be given to the field testing of existing equipment for ground military purposes by:

1. Installation of a Navy AN/ASQ-1 in a military aircraft at the Signal Corps Aviation Center.

2. Cooperative testing with Navy of equipment, AN/ASQ-8, installed in a navy blimp.

12.4 Detection of Combustion Products

Little information was found bearing on sensing through analysis of peculiar chemical components which might be associated with military equipment or formations. The University of Connecticut report for Project TACIT indicates skepticism that identifiable patterns of chemical components can be found by air sampling using a mass spectrometer, the most refined technique for detection of small quantities of chemicals in large samples. This opinion is based on consideration of the dissipation and rapid diminution of any such characteristic gases by unpredictable air currents.

12.41 Reference has been found to Navy experiments measuring variations in air ionization associated with the track of vessels at sea. Apparently the combustion components produced detectable gradients in the earth's electrostatic field. No information was found to serve as

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

12-7

a basis for estimate of the possibilities of utilization of this technique for the detection of land-borne motorized columns. It is apparent, however, that large groups of mechanized equipment in motion produce quantities of combustion components comparable in magnitude to those produced by vessels at sea.

12.42 It is concluded that insufficient data were available on the density of combustion components in the atmosphere over military equipment and formations, on the sensitivity of possible detecting equipments, and on the existence of stable identifiable patterns over targets of military interest.

12.43 Recommendations.

a. That additional information be obtained on the Navy ionization detection work to serve as a guide in the evaluation of possible military application.

b. That field testing of parameters involved in the application of the detection of combustion components be undertaken to establish a sound basis for further evaluation of this technique.

12.5 Field Experiments on Military Equipment

The sensing means under consideration by TEOTA are effective through the mechanism of radiation from the target military equipment or personnel, or reflections from such targets. In other words the "fingerprints" and "signatures" of the various items to various radiations are detected.

12.51 Little data were found on amplitude versus frequency spectra;

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

12-8

available information was generally non-quantitative, scattered, or taken under non-controlled conditions. For example: reports contain the notation that vehicles have been detected at distances of the order of several miles by acoustical methods, but no sound spectra produced by various military vehicles were found. Similarly there is indication of the detection of ground military materiel by magnetic airborne detectors, but the magnitudes of the magnetic field distortion produced at various altitudes apparently has not been determined. Even less information is available in the new field of thermal microwave radiations, in which only theoretical computations seem to have been made.

It is believed that individual tanks and vehicles, groups of tanks up to the size of a tank battalion, typical convoys, mortars, field guns should be tested. It is believed that acoustic, seismic, radio, radar, infra-red, magnetic field distortion patterns should be obtained as well as others. Detailed planning is required for such a test to determine both the control conditions and the data to be taken.

Airborne sensing means will probably be required for the longer distance ranges under consideration by this project, so patterns are required from elevations over the targets. It is difficult to control the experimental conditions when aircraft are used as the platforms for the measuring equipments. Also in some instances, presence of the aircraft would produce unwanted interference with the experimental data. Accordingly it is believed consideration should be given to the

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

12-9

use of wooden structures and captive balloons to carry the sensing devices for the experiment.

The availability of military materiel for experimental purposes has not been determined. In view of the nature and amount of military materiel involved it would probably be more feasible to undertake the experiment at some location where the equipment and firing ranges are available, rather than at a laboratory. Testing might be accomplished at maneuvers, but it is doubtful that conditions of experiment could be adequately controlled if the test were combined with a training maneuver.

12.52 Conclusions

1. That data on the emission and reflection characteristics of various military equipments and formations are the basis of quantitative consideration of proposed sensing devices and, therefore, the basis of any broad program in the field of sensing devices.

2. That comprehensive quantitative data are lacking on the sound, light, infra-red, radar and other spectra of military equipment and formations.

3. That data could be obtained by a one-time comprehensive field test at a military post having armored units and field equipment.

4. That testing during maneuver periods is not desirable.

12.53 Recommendation

That a study and planning task be initiated to collect and collate existing information on the radiation and reflection character-

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

12-10

istics of military equipment; and to plan controlled experiments to
be undertaken about July 1953 for the purpose of obtaining comprehensive
quantitative data of that type.

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

APPENDIX I

ORGANIZATION OF TEOA STUDY GROUPS

1. SECRETARIAT

Clements, Mr. S. E.	Syracuse University, Syracuse, N.Y.
Priest, Mr. C. A.	General Electric Co., Syracuse, N.Y.
Rives, Brig. Gen. Tom (ret.)	General Electric Co., Syracuse, N.Y.
Seely, Dr. S.	Syracuse University, Syracuse, N.Y.
Uhrhane, Col. F. F.	Office of Chief Signal Officer
Yamins, Mr. H. G.	Signal Corps Engineering Lab. Cambridge, Mass.

2. EDITORIAL STAFF

Clements, Mr. S. E.	Syracuse University, Syracuse, N. Y.
Seely, Dr. S.	Syracuse University, Syracuse, N. Y.
Uhrhane, Col. F. F.	Office of Chief Signal Officer

3. TASK GROUP #1 - RADAR - (Chief-Mr. W. Hausz)

Hausz, Mr. Walter	General Electric Co., Syracuse, N. Y.
Atchison, Dr. F. S.	National Bureau of Standards, Corona, Calif.
Evers, Mr. James T.	Signal Corps Engineering Lab. Asbury Park, N.Y.
Herman, Mr. Elvin E.	National Bureau of Standards, Corona, Calif.
Laurent, Mr. George	Philco Corporation, Philadelphia, Pa.
Lovett, Major Olin R.	Wright Air Development Center, Dayton, Ohio
McLamore, Mr. John	Radio Corporation of America, Camden, N.J.
Page, Dr. R. M.	Naval Research Lab., Washington, D.C.
Seely, Dr. Samuel	Syracuse University, Syracuse, N.Y.
Yamins, Mr. H. G.	Signal Corps Engineering Lab. Cambridge, Mass.

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

TASK GROUP #2 - COMMUNICATIONS - DATA TRANSMISSION
(Chief-Mr. A. Trevor)

Trevor, Mr. Bertram A.	R.C.A. Lab. Div., Princeton, N.J.
Brenner, Mr. M. M.	Coles Signal Laboratory, Red Bank, N.J.
Goldman, Dr. Stanford	Syracuse University, Syracuse, N.Y.
Greenblum, Mr. Carl	Evans Signal Lab., Belmar, N.J.
Hustan, Mr. Benjamin F.	National Bureau of Standards, Corona, Calif.
Shostak, Mr. Arnold	Office of Naval Research
Tradup, Mr. A.	Bell Telephone Labs., New York, N.Y.
Pullen, Mr. K. A.	Ballistics Research Laboratory Aberdeen Proving Grounds

CONSULTANTS:

Affel, Mr. H. A.	Bell Telephone Labs., New York, N.Y.
Clements, Mr. S. E.	Syracuse University, Syracuse, N.Y.
Sieck, Mr. L. W.	AFDRD

TASK GROUP #3a- INFRA RED (Chief-Dr. John Baird)

Baird, Dr. John	General Electric Co., Ithaca, N.Y.
Billings, Mr. Bruce	Baird Associates, Boston, Mass.
Brown, Mr. George E.	ERDL, Fort Belvoir
Cogswell, Lt. B. F.	ONR, Washington
<u>Alternate:</u> Isakson, Mr. Frank B.	" "
Dauber, Mr. Harry	SCEL
Fredrickson, Dr. W. R.	Syracuse University, N.Y.
Morton, Mr. George A.	RCA, Camden, N.J.
Mundis, Mr. Lloyd G.	National Bureau of Standards, Corona, Calif.

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

TASK GROUP #3a - Cont'd.

Owrebo, Dr. Paul J.

Wright Air Force Development Center
Dayton, Ohio

Warren, Major M. W.

USAF Directorate of Research and
Development, Washington, D.C.

TASK GROUP #3b - ACOUSTICS (Chief-Dr. R. B. Lindsay)

Lindsay, Dr. R. B.

Brown University, Providence, R.I.

Baird, Dr. John

General Electric Co., Ithaca, N.Y.

Berger, Mr. Kenneth

Signal Corps Engrg. Lab.
Ft. Monmouth, N.J.

Cook, Dr. Richard K.

National Bureau of Standards

Alternate:

Chrzanowsky, Dr. Peter

" " " "

Kock, Mr. Winston

Bell Telephone Labs., Murray Hill, N.J.
(thru Mr. Affel - part time only)

Nyborg, Dr. Wesley L.

Brown University, Providence, R.I.

Olson, Dr. Harry E.

R.C.A. Laboratories, Princeton, N.J.

Alternate:

Hackley, Mr. R. A.

" " " "

Peterson, Dr. Eugene

Bell Telephone Labs., Murray Hill, N.J.

Powers, Mr. A. B.

National Bureau of Standards,
Corona, Calif.

Reep, Dr. Robert

Philco Corporation, Philadelphia, Pa.

Weber, Mr. Paul

Bureau of Ships, Washington, D.C.

Alternate:

Ullman, Mr. Jack D.

" " " " "

TASK GROUP #3c - PHOTOGRAPHY (Chief-Dr. William A. Shurecliff)

Shurecliff, Dr. William A.

Polaroid Corporation, Cambridge, Mass.

Crews, Comdr. H. W.

CNO

Alternate:

Ruffner, Major P. M.

Marine Corps

Hardy, Dr. Arthur C.

Mass. Inst. of Technology,
Cambridge, Mass.

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

TASK GROUP #3c - Cont'd.

Land, Dr. Edwin H.	Polaroid Corp., Cambridge, Mass.
Mazlow, Mr. Bernard	Signal Corps Engrg. Lab., Ft. Monmouth, N.J.
Tarkington, Mr. Raife G.	Eastman Kodak Co., Rochester, N.Y.
Warren, Major Myron W.	Directorate of Research & Development Pentagon, Washington, D.C.
Willcox, Mr. Frederick T.	Fairchild Camera & Instrument Corp., Jamaica, L.I., N.Y.

CONSULTANTS:

Hancock, Lt. Col. John	Wright Field
Webb, Lt. Col. M. L.	Army Field Forces Liaison Officer, SCEEL
Quick, Maj. J. R.	Wright Field
Ruffner, Maj. P. M.	U. S. Marine Corps
Sheahan, Maj. W. M.	OCSigO, Army Pictorial Division

TASK GROUP #3d - WEATHER (Chief-Dr. Harry Wexler)

Wexler, Dr. Harry	U. S. Weather Bureau, Washington, D.C.
Fister, Mr. E. J.	Signal Corps Engrg. Labs., Ft. Monmouth, N.J.
Hafsted, Miss Kay	Operations Research Office, Johns Hopkins Univ.
Hall, Mr. Ferguson	U. S. Weather Bureau, Washington, D.C.
Rex, Lt. Com. Daniel F.	OP Nav. Pentagon, Washington, D.C.
<u>Alternate:</u> Palmer, Lt. Com. Charles A.	ONR, Bldg. T-3
Shtogren, Lt. Col. Anthony	USAF, Langley Field

CONSULTANTS:

Yamins, Mr. H. G.	SCEEL

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

TASK GROUP 1 - Cont'd.

CONSULTANTS:

Ference, Mr. Michael, Jr.	SCEL
Njus, Lt. Col. O.	Air Weather Service
White, Mr. F. D.	U. S. Weather Bureau
Colman, Mr. R. N.	U. S. Weather Bureau

TASK GROUP 2 - PHOTOELECTRIC SYSTEMS (Chief-Dr. J. F. Koehler)

Koehler, Dr. Joseph F.	Philco Corporation, Philadelphia, Pa.
Alpers, Mr. Fred	National Bureau of Standards, Corona, Calif.
Buckley, Mr. John	Raytheon Corp., Newton, Mass.
Chadleigh, Mr. Walter W., Jr.	Philco Corporation, Philadelphia, Pa.
Farnsworth, Mr. Elmer	Capehart-Farnsworth, Ft. Wayne, Ind.
Glasford, Dr. G. M.	Syracuse University, Syracuse, N.Y.
Goldmark, Dr. Peter G.	Columbia Broadcasting System, N.Y.
Goldsmith, Mr. Thomas T., Jr.	Dumont Television Labs., Passaic, N.J.
Henderson, Mr. ...	Capehart-Farnsworth, Ft. Wayne, Ind.
Herschrother, Mr. R. C.	Raytheon Corp., Newton, Mass.
Larson, Mr. C. C.	Capehart-Farnsworth, Ft. Wayne, Ind.
LeVine, Mr. Richard B.	Coles Signal Labs., Ft. Monmouth, N.J.
Loughran, Mr. A. V.	Hazeltine Corp., Little Neck, N.Y.
Marshall, Mr. Charles A.	Wright Air Development Center, Dayton, Ohio
McIlwain, Dr. Knox	Hazeltine Corp., Little Neck, N.Y.
Mertz, Mr. P.	Bell Telephone Labs., New York City
Nobles, Mr. Charles E.	Westinghouse Electric Corp. Baltimore, Md.

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

TASK GROUP #7b - Cont'd.

Lanham, Mr. Gerald

National Bureau of Standards,
Corona, Calif.

LePage, Dr. W. R.

Syracuse University, E. Syracuse, N.Y.

Diehr, Mr. A. S.

Naval Research Lab.

Nelson, Mr. J. W., Jr.

General Electric Co., Syracuse, N.Y.

Och, Mr. H. G.

Bell Telephone Labs., Whippany, N.J.

Palmer, Mr. Winslow

Sperry Gyroscope Co., Great Neck, N.Y.

Peterson, Mr. Joel

Bendix Aviation Corp., Teterboro, N.J.

Pike, Dr. E. W.

Raytheon Mfg. Co., Newton, Mass.

Sieck, Mr. Lewis W.

AFDRD, Pentagon, Washington, D.C.

Siglin, Mr. P. W.

Evans Signal Lab., Belmar, N.J.

Swartzel, Mr. Karl D.

Cornell Aero Lab., Buffalo, N.Y.

Pullen, Dr. K. A.

BRL, Aberdeen Proving Ground

SECRET
SECURITY INFORMATION

SECRET
SECURITY INFORMATION

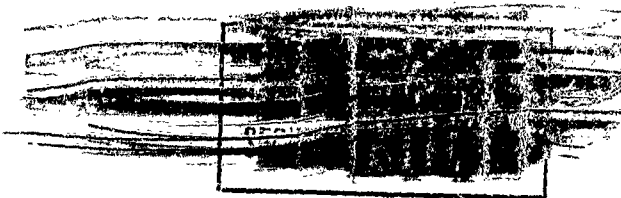
APPENDIX 2

TEOTA MEMORANDUM

Much of the material used in the TEOTA project was accumulated in the form of technical reports from the individuals and committees who worked on the project. In total these reports were considered too extensive to warrant their inclusion as appendices to the final report. For reference purposes these reports have been indexed as TEOTA MEMORANDA as follows:

1. Anti-Personnel Radar, Dr. R. M. Page, NRL, 10 Oct. 52, 3 pgs. (C)
2. The Passive Detection of Thermal Radiation at Microwave Frequencies, F. C. Lewis, Raytheon Corp., 22 Oct. 52, 10 pgs. (S)
3. Short Range Navigation in Rough Terrain, E. W. Pike, Raytheon Corp., 28 Oct. 52, 6 pgs. (S)
4. Field Artillery as an Aid in Navigation for Reconnaissance Purposes, W. R. LePage, Syracuse University, 28 Oct. 52, 5 pgs. (C)
5. Control, J. D. Peterson, Bendix Aviation Corp., 29 Oct. 52, 7 pgs. (S)
6. A Suggested Alternative Target Locating System, E. W. Pike, Raytheon Corp. 5 Nov. 52, 2 pgs. (S)
7. A Suggested CW Radar System for Short-Range Battlefield Surveillance, E. W. Pike, Raytheon Corp., 6 Nov. 52, 4 pgs. (S)
8. Notes on Automatic Focus Control and Image Trackers, E. W. Pike, Raytheon Corp., 6 Nov. 52, 2 pgs. (S)
9. Dual Range Navigational Systems, K. D. Swartzel, Cornell Aeronautical Laboratory, 10 Nov. 52, 16 pgs. (S)
10. Drone Operation and Control, E. W. Pike, Raytheon Corp., 11 Nov. 52, 6 pgs. (S)

SECRET
SECURITY INFORMATION

- 
11. Surveying Methods, E. W. Pike, Raytheon Corp., 11 Nov. 52, 4 pgs. (S)
 12. Polar Coordinate Techniques, H. G. Och and A. A. Currie, Bell. Tel. Labs., 12 Nov. 52, 18 pgs. (S)
 13. Automatic Map-Matching, W. R. LePage, Syracuse University, 13 Nov. 52, 5 pgs. (S)
 14. Altimeters, W. R. LePage, Syracuse University, 13 Nov. 52, 2 pgs. (S)
 15. Double Angle Measuring Systems for Navigation, K. A. Pullen, 5 pgs. (S)
 16. Polar Coordinate Navigation Systems, P. W. Siglin, SCEL, undtd, 5 pgs. (S)
 17. Velocity Integration Navigation System, L. R. Everingham, Cornell Aeronautical Laboratory, 15 Nov. 52, 25 pgs. (S)
 18. Hyperbolic Systems, W. Palmer, Sperry Gyroscope Co., undtd, 52 pgs. (S)
 19. Data Transmission - State of the Art, Millard M. Brenner, Coles Signal Laboratory, 50 pgs. (C)
 20. Zero Beat High Resolution Radar, W. Hausz, General Electric Co., 11 Oct. 52, 19 pgs. (S)
 21. Balloon Vehicles, F. B. Jewett, General Mills, 17 pgs. (S)
 22. Performance Characteristics of Present and Future Aircraft affecting Reconnaissance Capabilities, C. Wood, NACA, 12 pgs. (S)
 23. Weapons carrying Drones of the Petrel Family, Hunter A. Boyd, NBS, 4 pgs. (S)
 24. The Piloted High-Performance Vertical Rising Vehicle for Reconnaissance, R. A. Wolf, Cornell Aeronautical Lab., Inc., 8 pgs. (S)
 25. Landmarking, Eugene W. Pike, Raytheon Corp. 17 pgs. (S)
 26. Direction Reference Systems, F. E. Houston, 4 pbs. (S)
 27. Preliminary Quantitative Data Concerning Microwave Communication, Stanford Goldman, Syracuse University, 6 pgs. (S)
- 

28. Some Aspects of Short Range Transmission, A. Tradup,
Bell Telephone Lbs., 6 pgs. (S)
29. A communications Intercept and Analysis System for
Battlefield Surveillance, Carl Gressholm, Evans Signal
Lab., 6 pgs. (S)

