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# Massachusetts Institute of Technology

## Defense of North America

*Final Report*

*of*

# Project Lamp Light

15 March 1955

Volume IV

of 4 volumes

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**DEFENSE AGAINST THE SEABORNE THREAT**

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## CHAPTER 14 DEFENSE AGAINST THE SEABORNE THREAT

### INTRODUCTION

The purpose of this chapter is to examine the seaborne threat that may be posed against the North American continent, to assess its importance and to relate it to the air threat, to present a defense system to counter the seaborne threat, and, finally, to insure where possible that the proposed system shall be compatible with that required to meet the air threat.

It would be relatively simple and inexpensive, and within Russian capabilities, to utilize existing shipping, surface and subsurface, for a number of objectives, including:

Carrying, launching and controlling airborne missiles with nuclear warheads.

Delivery of nuclear explosives in port areas either as bottom-laid mines or within an abandoned hull.

Attack on picket ships of the air defense system.

So far as the degree of the seaborne threat is concerned, it is believed that:

Although the magnitude of this threat is less than that of the airborne threat, it is nevertheless a secondary threat of appreciable magnitude,

While a seaborne attack may not be used alone, it is a possible adjunct to air attack,

Improved air defense encourages use of the alternate seaborne attack.

Therefore measures necessary to meet both the seaborne and air threat to the North American continent must be developed as parts of the same plan.

### OBJECTIVES OF SEA SURVEILLANCE

Early in the Project Lamp Light study, it became clear that the first step in defense against the seaborne threat should be a system that detects, identifies and maintains a track on all targets, surface and subsurface.

It would be advantageous to extend surveillance over the entire sea areas; however, economy may preclude that objective in the initial period, pending further research and development on low-cost detectors with search capability over large areas. An acceptable alternative appears to be surveillance in a zone of maximum sensitivity contiguous to the North American continent, together with information lines in remote areas - a geographic distribution similar to that suggested for the air threat.

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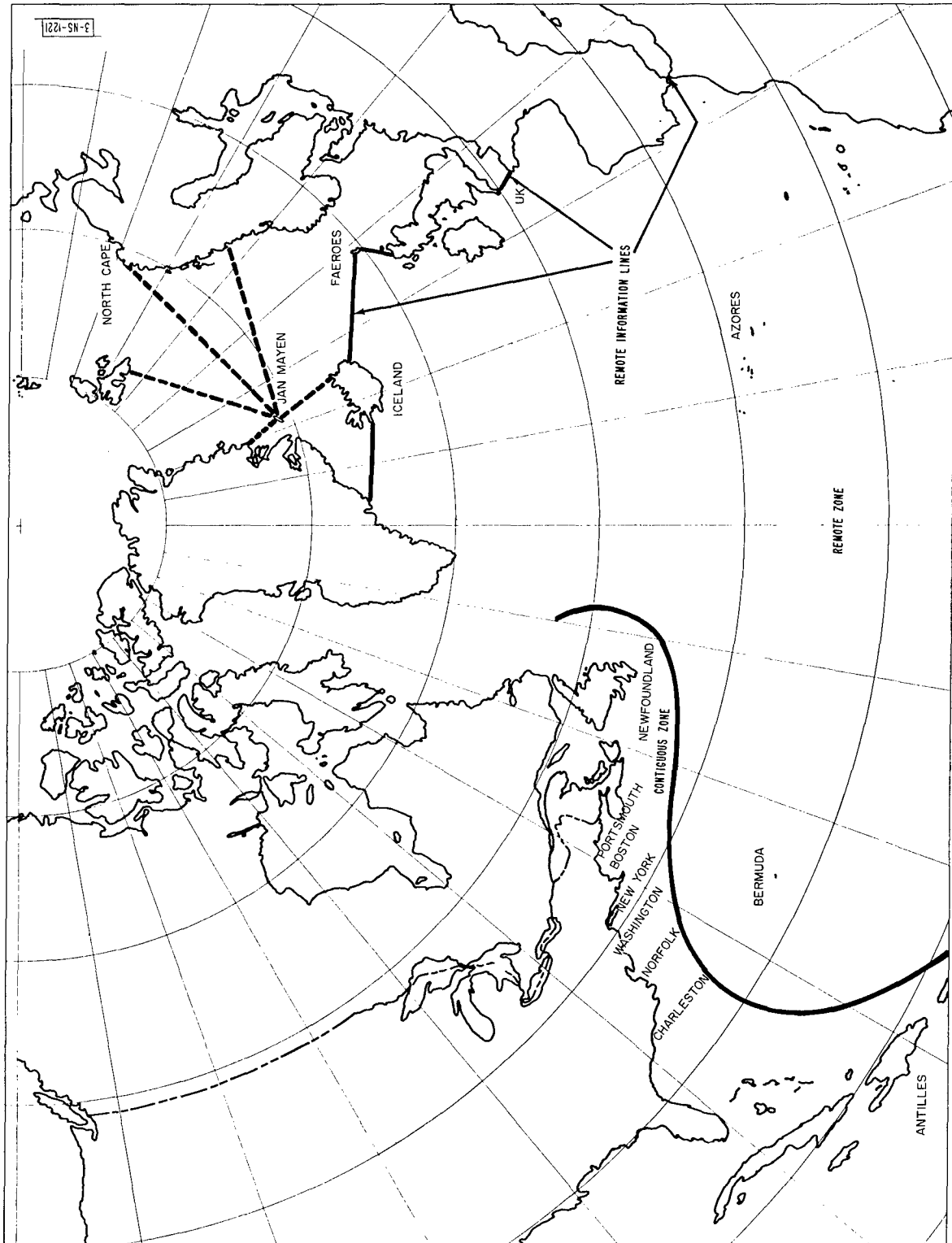


Fig. 14-1. Sea surveillance zones.

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The distance beyond the contiguous zone to which offshore surveillance should extend is presently determined by the enemy's missile-launching range; however, the extent must be sufficiently greater than that range in order to insure detection, identification and reaction outside the critical range. Based on available intelligence estimates, a contiguous zone of 600 miles depth appears adequate for the near period.

Surveillance lines may be established in remote areas to provide early information of the penetration of enemy vessels, both surface and subsurface. In the Atlantic, geography favors the establishment of lines that can effectively enclose ports of origin for both surface and subsurface Soviet vessels; however, in the Pacific, it is doubtful if effective enclosure can be achieved.

For the Atlantic, the proposed contiguous zone and the remote information lines are shown in Fig. 14-1. A similar contiguous zone is proposed, but not shown, for the Pacific Ocean.

## General

### SEA SURVEILLANCE

In its early form, the system proposed by Lamp Light effects electromechanical implementation of an existing Navy system and, it is believed, will provide a significant deterrent to enemy seaborne action.

Later, the growth potential of the system is realized by the addition of new or improved data sources, at which time it will effectively detect, identify and track a high percentage of all targets. In this form, it is believed that the system may deny the enemy the use of the seaborne attack.

A unique characteristic of the seaborne attack is its probable penetration through a high density of friendly shipping. One expects, on the average, about 1000 ships at any time in the contiguous zone off the North American Atlantic Coast. This number is large compared with the small number of enemy penetrations that could cause severe damage, - namely, six or less, depending on their multiple missile-launching capability. To insure identification and detection of enemy penetrations against such a large background of friendlies requires rather high values of the probabilities of those functions; the growth potential of the present system should make it possible to attain these values. However, the existence of even relatively low values of those probabilities may provide a deterrent to enemy seaborne action, and such can be realized by the initial form of the proposed system in the early time period.

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The search for six ships among a thousand may, at first thought, appear like looking for a needle in a haystack; however, one can find iron needles easily with a strong magnet: technological means are now available (see p. 14-8 et seq.) with which it is believed the sea surveillance can be similarly effected.

Another obstacle to sea surveillance is the general opacity of sea water to the communication of intelligence; however, here again technological methods are proposed (see p.14-10) which it is believed will be effective.

Thus there is now confidence that the proposed system will work and be effective in providing surveillance against both the surface and subsurface threat.

## Data Sources

In order to detect, identify and track seaborne targets, data sources are needed. Study of possible sources reveals that no single source is adequate; however, the data from several sources can be combined and analyzed with excellent results. Various sources that have been considered include the following.

Radar can detect the presence and position of surface targets; repeated looks can develop course and speed. The identification of ship targets from the radar plot is partial, at best, and for that purpose one turns to other data sources.

Sail Plans can be used to predict the probable distribution of a large percentage of ships in the contiguous zone. It is believed that such a percentage, comprising U. S., U. K., and other NATO ships, will cooperate. Given this participation, an appreciable fraction of all contiguous shipping can be identified through the comparison of the radar plot and the predicted shipping distribution. However, not all ships can thus be identified, since, for example, sail plans change, some ships will not cooperate, etc. For the remaining fraction, one must rely on still other data sources.

Ships' Own Reports. It is recommended that each ship report periodically its identity, position, course and speed. Initially, reports may be made by available ship communication, recalling that such radio facilities, together with ocean station communication centers, have been recommended for surveillance in Chapter 13. (The existence of a system of general surveillance is assumed in this chapter.) Later, it may be feasible to develop a ship transponder or beacon for automatic reporting. Again, it is believed that friendly shipping will cooperate when the need is made clear.

Ships' Characteristics. Tables of ships' characteristics are useful sources of data. They include ownership, registry, pertinent history of past operations, and physical characteristics such as radar cross section, noise sources, etc. All these comprise

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a large quantity of data, since there were 32,385 powered ships, each larger than 100 tons, afloat in 1954, according to the latest Lloyds Register of Shipping. The same reference notes that the largest 10,000 of these ships average 4124 tons each, and that one-third of all tonnage afloat is diesel-powered. The latter characteristic, for example, implies a noise source that will be useful in the underwater detection and identification of such ships.

The Radio High-Frequency Direction-Finding Net provides another useful data source. Underwater Sound appears to be the most versatile and useful of the underwater detectors and it can provide detection and identification of both submerged and surface targets.

## Data Processing

Because of the important cross-relationship between sonic and other detectors, it is essential that the data from surface and subsurface targets be analyzed and displayed by the same system. For example:

Radar forces the surfaced submarine to submerge,

The submerged submarine is detected sonically,

The established Lofar track is continued by Radar when the submarine surfaces,

Ships seen in the radar plot may be identified by comparing their Lofargrams and Ships' Characteristics File

An electromechanical computer is required for the storage and analysis of the data because of the quantity of data and the speed of analysis necessary, which, while less than that of the air-surveillance case, is nevertheless appreciable. In addition, the replacement of men by computation machines is good business practice, as is illustrated by the experience of such organizations as insurance companies who have similar problems. Fortunately, a commercially available digital storage-type computer of either the IBM Type 704 or the Remington Rand Type 1103 appears to be adequate for the proposed system. It should be noted that there are a number of benefits, incidental to the solution of the main surveillance problem, which derive from use of the proposed electromechanical computer. The large amount of data thus stored may be automatically referred to for the rapid and frequent compilation of reports of several types. For instance, it would be easy to:

Report the distribution of all ships at a given time,

List the past activities of a particular ship, or a group of ships for past periods of a year or more.

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Show the past shipping operations at particular points, such as at a tentative Texas Tower site, for example.

A number of similar reporting operations to which the computer may be applied will be obvious to the reader. An important point is the speed and low cost of these incidental benefits. Appendix 14-D contains a detailed discussion of data processing for sea surveillance.

## Description of Sea Surveillance System

The functional outline of the proposed system is shown in Fig. 14-2, which combines the data sources just described together with the several outputs. The latter include a video display, skunk and submarine alarm, and various information to command and other authorities.

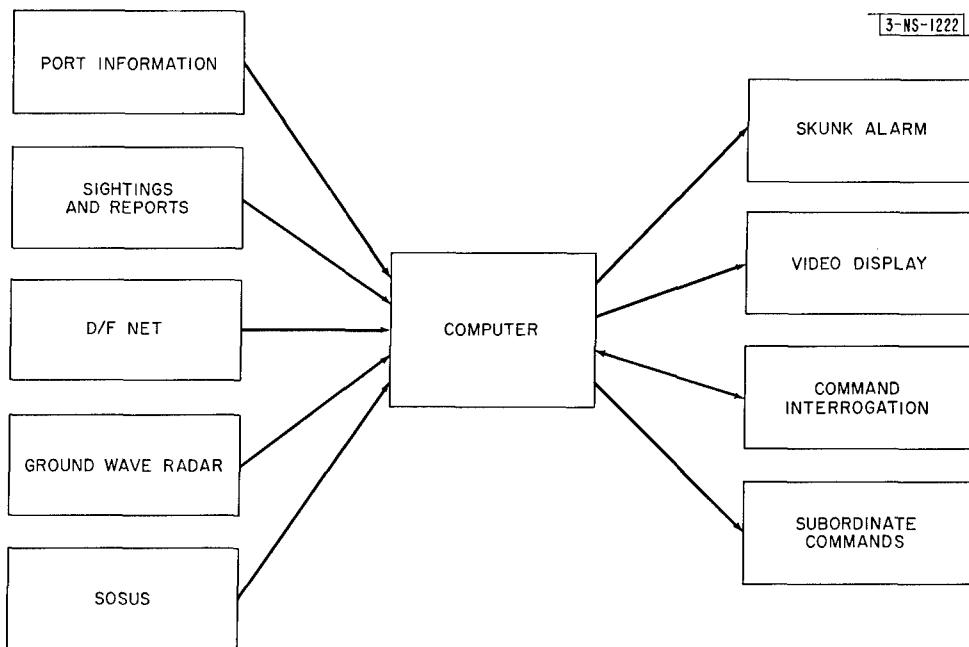


Fig.14-2. Proposed sea surveillance system – functional outline.

A suggested plan layout for the Sea Surveillance Center is shown in Fig. 14-3. Two computers are required, one for a spare during maintenance or other periods when the first is inactive; also, the additional computer is available for report compilation. The Center includes a vertical display on which a summary plot is maintained; it includes four sector oscilloscopes on which portions of the ocean-shipping areas are displayed and monitored by operators; it includes a video display for the Sea Traffic Officer; it

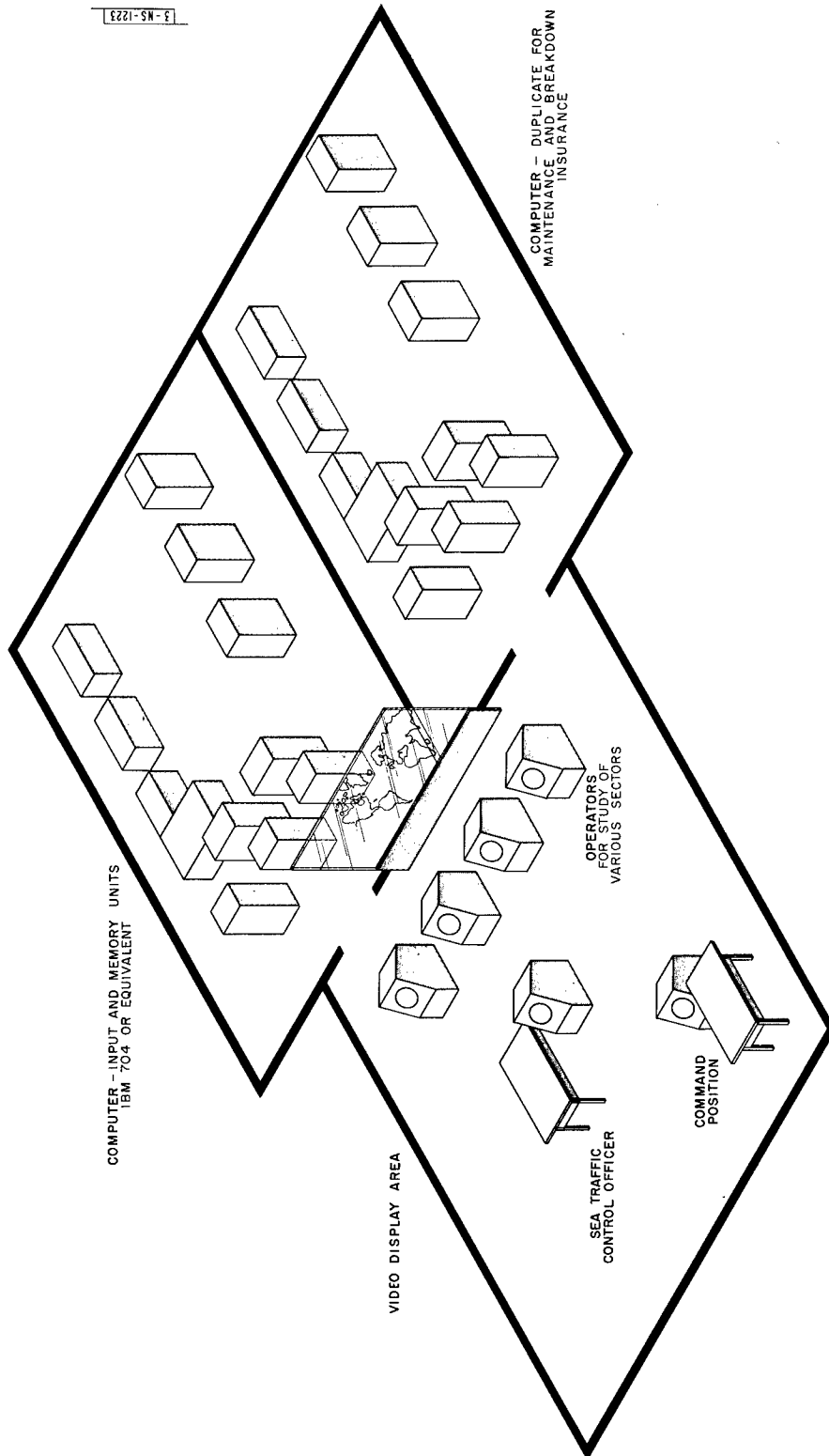


Fig. 14-3. Schematic display of sea surveillance center.

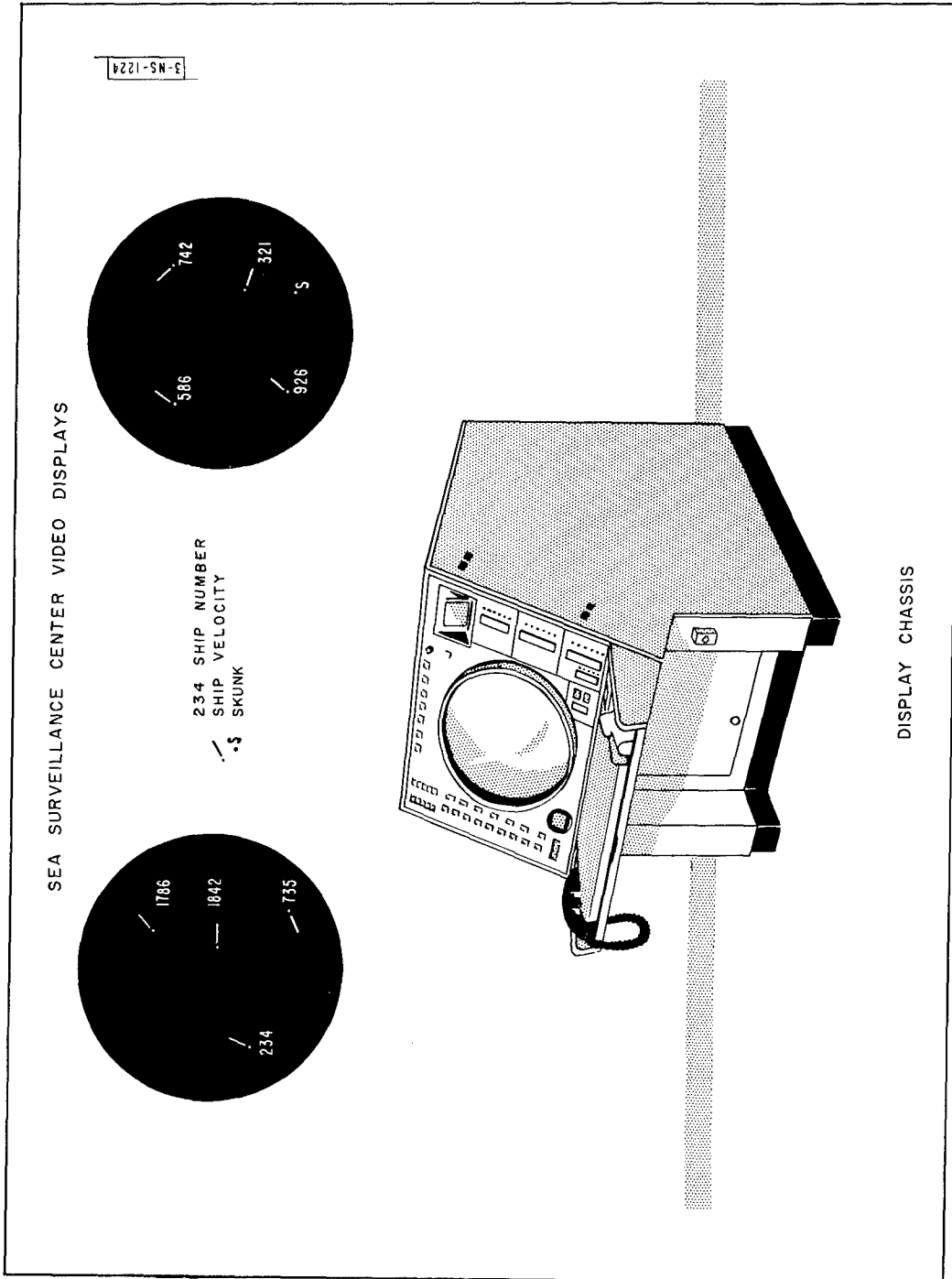


Fig. 14-4. Sea surveillance center — video displays.

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includes a display for Command which has access to all information within the computer.

The proposed oscilloscope video displays are shown in more detail in Fig. 14-4, which includes views of the chassis and of the tube display. The latter shows course, speed, position and identity of all targets; skunks are identified by the letter S; the use of Charactron-type tubes for this purpose is proposed.

## IMPROVEMENTS IN DATA SOURCES

The proposed system should be implemented and activated as soon as possible by use of available data sources. When this is done, a significant deterrent to enemy seaborne action will be achieved. It is also recommended that work on the development of new and improved data sources be undertaken at the same time and in parallel with the initial systems effort. When the latter sources are incorporated into the system – and it is recommended that this be achieved on an expedited basis – the effective detection, identification and tracking of seaborne targets may be achieved. At that time, it may be possible to deny the enemy use of the seaborne threat.

Among the necessary developments that should be undertaken are improvements in radar and in underwater detection.

### Radar

In the initial system, reliance must be placed on radar coverage provided by AEW aircraft. These may include planes on search for surface targets particularly and those proposed in Chapter 13 for use against the air threat. The proposed deployment of the latter aircraft was also described in that chapter and the coverage thereby achieved is comparable with the contiguous zone proposed in this chapter. The communication and handling of the data from AEW aircraft is found in Chapters 6 and 7. It may be desirable to use radar reports from MATS and certain commercial aircraft.

A major shortcoming at the present time is the lack of a ground-based radar that has low-altitude performance at long range. It appears to be technically possible to develop such a radar for the detection of shipping targets from a shore-based station at ranges up to 500 miles. The advantages of such a radar are obvious. They include: low cost, all-weather reliability, high search rate (which is important in order to obtain high probabilities of detection and identification), easy extension to new areas of coverage, and no diversion of AEW aircraft from the primary air-search function. It appears that ground-wave radar at about 2 mcps can be applied to this purpose, i.e., the detection of shipping targets at long range. It is worth noting that the same radar

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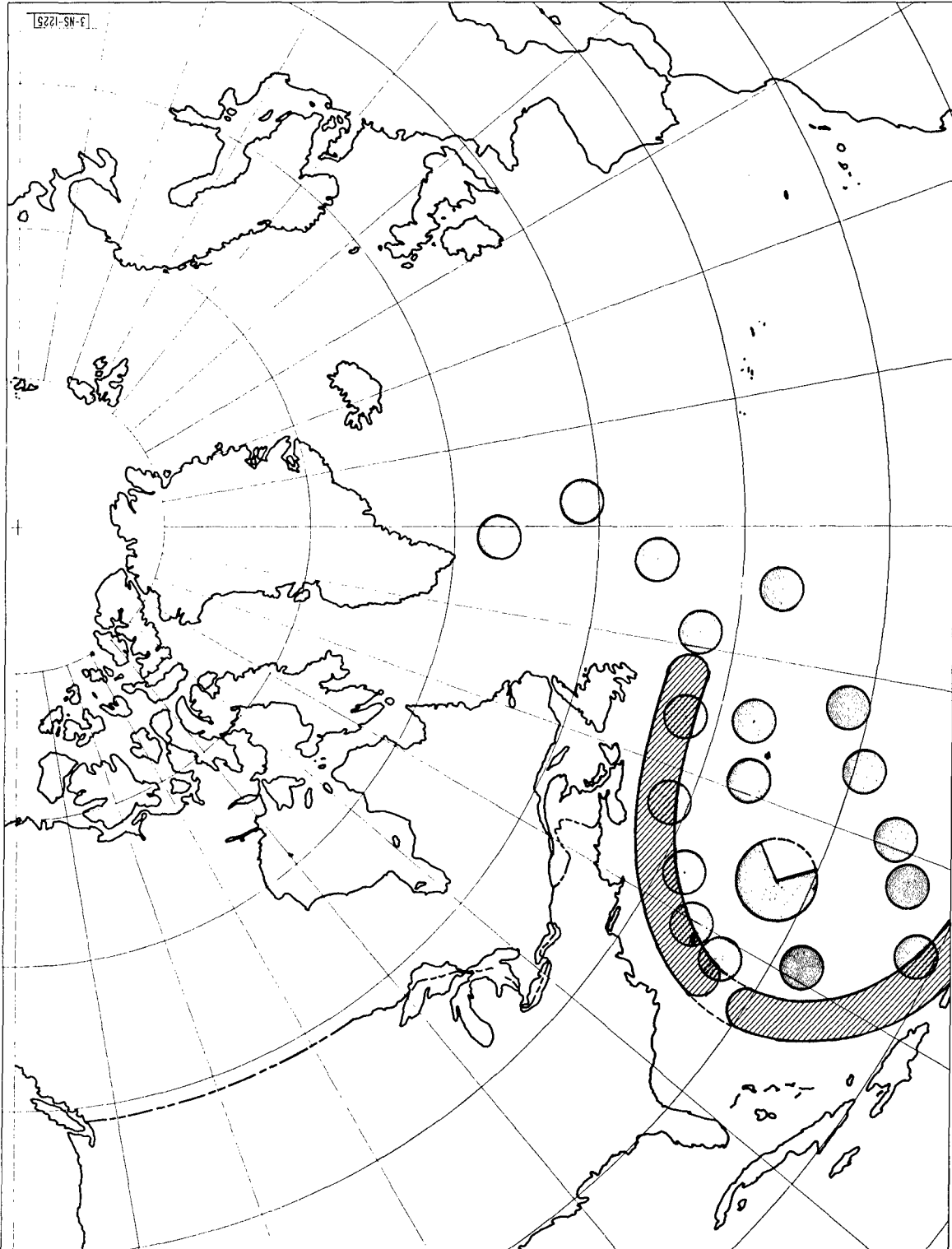


Fig. 14-5. Subsurface surveillance system.

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may not detect air targets of smaller cross sections than those of ships. The technical aspects of ground-wave radar are discussed more fully in Appendix 14-A. It is concluded therein that a full-scale experiment of the ground-wave radar, including high antenna gain, is essential in order to evaluate the possible system performance. Such full-scale experiments are urgently recommended.

Underwater Detection. A conference of technical experts\* was assembled to review possible underwater detectors, primarily against the submarine threat. This conference reconfirmed the supremacy of sonic detectors for the difficult underwater problem. The following conclusion is most important: A major stumbling block to the development and use of underwater detection equipment, is the lack of hydrographic data, particularly in northern waters. The accumulation of such data is urgently recommended. Areas of interest include those of the remote information lines shown in Fig. 14-1. The types of hydrographic data that are of particular interest include noise sources, propagation at low frequencies, and properties of the ocean bottom.

In the near period, reliance must be placed on passive detection systems. Available equipments must be deployed over increased areas, and improved; some new developments of such equipment are required. Developments of this type are discussed in Appendix 14-B. It is recommended that:

The planned installation of Lofar be expedited. Assuming a 90 per cent detection probability at 200-mile range, the shore-based system will then give the coverage shown in Fig. 14-5.

Long-range, directional passive systems be developed for installation at or near picket ships which will monitor the equipment. Assuming the deployment of picket ships proposed in Chapter 12, together with a range of 100 miles on a snorkeling submarine, the coverage thus provided is shown in Fig. 14-5.

Passive detection equipment be deployed in shallow water in order to prevent end runs around the coverage shown in Fig. 14-5. Some such equipment is under development; we urge that this development be expedited.

For the future, we recommend the development of a long-range, low frequency, active sonic detection system on an expedited basis. Such a system is required in order to meet the threat of the quiet submarine which will defeat passive systems. The technical feasibility of a long-range active sonic detection system is argued in more detail

\*R.J. Christensen, Navy Electronics Laboratory; E.E. David Jr., Bell Telephone Laboratories; J.E. Henderson, Univ. of Washington; F.V. Hunt, Harvard University; Sir Charles Wright, Marine Physics Laboratory; and staff members of Project Lamp Light.

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in Appendix 14-C, the data of which are based in part on work now in progress at both Naval Research Laboratory and Naval Electronics Laboratory. On the basis of available data, it appears probable that a range of 120 miles in deep water and 30 miles in shallow water may be obtainable on a typical submarine cross section.

## Disposal of Skunks and Submarines

### ACTION AGAINST UNKNOWNNS

The proposed sea surveillance system will detect and identify a high percentage of seaborne targets as friendlies, assuming the final form of the system is implemented. If serious effort is put on the proper development and use of the system, it is believed possible to reduce the number of unknowns in the system to, say, less than 1 per cent, i.e., less than 10 unknowns. Now then, how should one dispose of the remaining unknowns? The answer is beyond the terms of reference of this project because it involves diplomacy and international law at high level. However it appears to us that:

The policy applied to skunk and submarine disposal must reflect current intelligence, the world situation and the number of unknowns present in the surveillance system, together with their distribution;

Under certain conditions it may be necessary to put the burden of proof on the penetrating target; or divert to non-critical ports those ships that fail properly to prove their friendliness.

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## CHAPTER 14 RECOMMENDATIONS

1. We recommend the establishment of 600-mile-wide contiguous sea surveillance zones off our coasts, supported by remote surveillance lines to provide early information.
2. We recommend the development, implementation and activation of sea surveillance systems in which digital computers are used to correlate data from radars, radio direction finders, and underwater sound detectors with sail plans, ships' reports, and tables of ships' characteristics. The resulting information on position, course, speed, and identity of all vessels is to be displayed in a summary plot for command purposes.
3. We recommend that a program of conclusive experiments be undertaken without delay to determine whether ground-wave radar at about 2 mcps can provide continuous tracking of all surface vessels within several hundred miles of the shore line.
4. We recommend an energetic program of oceanographic research, particularly in the North Atlantic where remote surveillance lines are needed.
5. We recommend the development of passive long-range sonic detectors for installation at or near picket ships, passive sonic detectors for deployment in shallow water, and active long-range, low-frequency sonic detectors to meet the threat of the silent submarine.

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**APPENDICES TO CHAPTER 14**

- APPENDIX 14-A GROUND WAVE RADAR
- APPENDIX 14-B SEA SURVEILLANCE SYSTEM
- APPENDIX 14-C LONG RANGE ACTIVE SONAR
- APPENDIX 14-D DATA FOR PROCESSING SEA SURVEILLANCE

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## APPENDIX 14-A GROUND WAVE RADAR

Vertically polarized radio waves having frequencies less than about 10 Mcps are propagated around the curvature of the earth. These so-called ground waves are the basis of the long-distance communication systems at low frequencies. At 15 kcps, signals can be sent completely around the earth. The attenuation of this mode of propagation increases with frequency and decreases as the conductance of the terrain over which it is propagated is increased. Figure 14A-1 gives the relative intensity of the ground wave over sea water as a function of distance for several frequencies.

The use of the ground wave for a ship-detection radar system has been proposed. At 2 Mcps, the wavelength is 150 meters, which is of the same order as the dimensions of a ship; hence we may expect the effective radar cross section at this frequency to approximate the geometrical cross section of the ship. In addition, external noise,

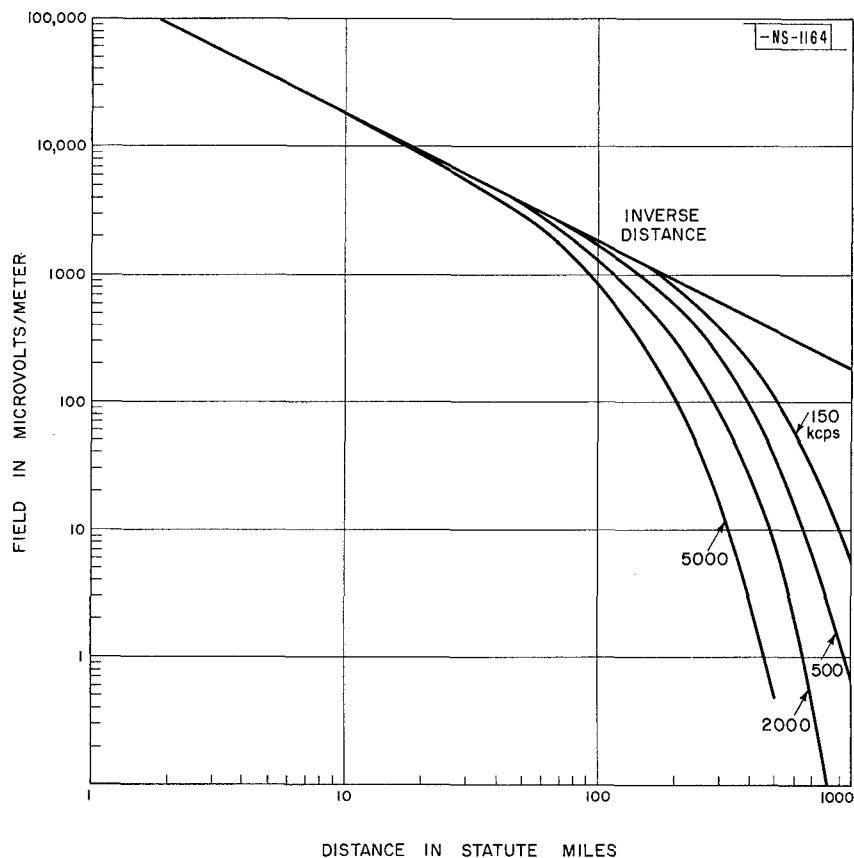


Fig. 14A-1. Intensity of ground wave over sea water as a function of distance. (From "Reference Data for Radio Engineers", third edition, published by ELECTRICAL COMMUNICATION. Reprinted by permission.)

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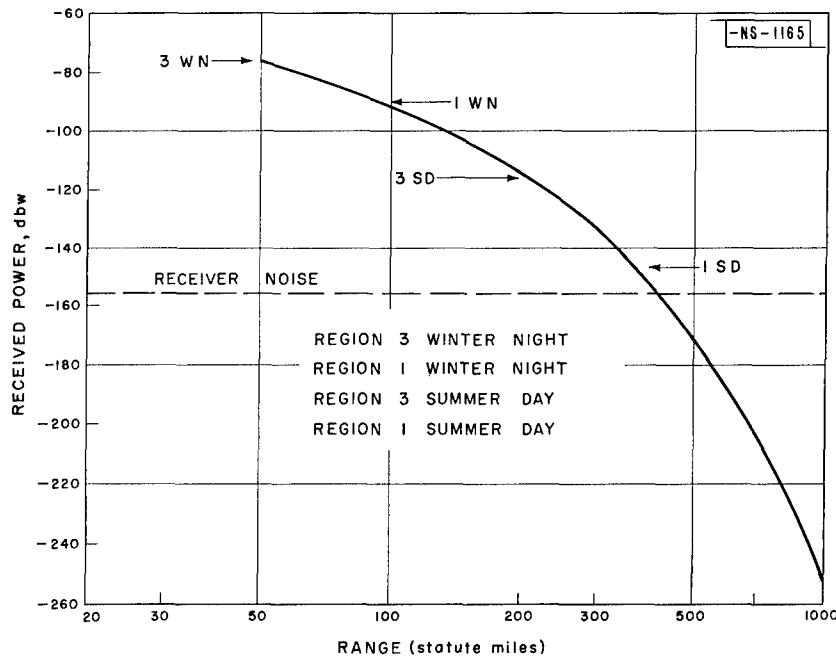


Fig. 14A-2. Received power in db relative to one watt vs range. Frequency 2 Mcps; transmitter power one megawatt; receiving and transmitting antennas each short vertical dipoles, target half-wave free-space vertical dipole. Dotted line is receiver noise for 20-kcps band with noise factor of 4. Arrows indicate noise power (rms noise fields) for 20-kcps bandwidth. Region 1 is the arctic and Region 3 is the mid-latitudes.

rather than internal receiver noise, is the limitation for detection, and the external noise is a minimum in the daytime at 2 Mcps. As in any radar system, the important considerations are transmitted power, signal attenuation, angular resolution, target cross section, noise level at the receiver, and extraneous return or clutter.

Figure 14A-2 shows the result of a calculation\* of the received power from a half-wave vertical dipole target (free space) assuming transmitting and receiving antennas to be short vertical dipoles and a transmitted power of one megawatt. Expected noise levels for various regions, seasons, and times of day are indicated in the figure, and it can be seen that, depending on the noise level, signal and noise are equal at from 50 to 360 miles range. A system that works well only in the day, although nearly useless for aircraft detection, can be very effective for detecting and tracking ships since they move so much more slowly.

The system discussed in Fig. 14A-2 can be improved in a number of ways. The transmitter power could be increased by 10 db or more. Antenna gains could probably be

\*This calculation was made by Dr. Joseph T. deBettencourt of Lincoln Laboratory, "Notes on Loran Radar" (1 November 1954).

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increased by 25 db (receiving and transmitting together). Signal-processing techniques at the receiver might allow detection of signals 10 db below the noise level. The added receiving-antenna directivity would decrease the noise at least in some directions. It may be that some frequency other than 2 Mcps would be better. Sea return may be a problem. A calculation\* of ship cross sections, assuming the ships to be perfectly conducting ellipsoids, has been made by Dr. Nelson A. Logan.

An exploratory research program using the Nantucket Loran transmitter has been carried on by a group at Lincoln Laboratory under the direction of Dr. J. T. deBettencourt. Echoes have been observed, but their exact origin has not yet been ascertained. Non-ionospheric echoes appear to come from seaward directions. This work is described in memoranda of Lincoln Laboratory.† Further research should be urgently carried on to determine the feasibility of a ground-wave radar system for ship detection.

*D.T. Stevenson*

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\*"Reflection Properties of Surface Targets in the Vicinity of 2 Mcps," Document No.S-3154, Air Force Cambridge Research Center.

†D.J. Gray, "States of Loran Radar Experiments," Lincoln Laboratory internal memorandum (22 December 1954).

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## APPENDIX 14-B SEA SURVEILLANCE SYSTEM

The general surveillance systems previously described are characterized by their ability to make use of a variety of information containing the characteristics of airborne or surface vehicles, for the purpose of tracking and identification. In such a system, the information from a large number of sensing devices can now be correlated and gainfully used. Specifically, sensing devices have been described that can be located on airplanes, ships, ground stations, etc., and that will feed information into a central computer system by means of a communications network. Such communications networks as described are diversified and use all available means of radio, telephone and telegraph systems.

In the detection of vessels that may or may not be submerged, a similar problem exists as with the detection of objects that travel on the surface or in the air. Extremely long-range detection is possible occasionally, but is reliable only when the source emits a large amount of noise. For the sonic<sup>1</sup>-detection devices to remain efficient and reliable, the range must be considerably reduced if the source becomes less noisy.

An attempt has here been made to set up a subsurface surveillance network, similar to the supersurface networks that have been described elsewhere in this report.

Fundamentally, the problem of tracking vessels that are partially or completely submerged would be relatively simple, if it were possible to put listening stations into the ocean at a very large number of locations. There the detection, tracking and identification job would be simple, provided that such a large number of detection stations could be tied together by means of a communications net feeding into a computer. This problem has been studied and is believed capable of reasonable solution. The system herewith presented is one such system.

Most man-made objects that we wish to detect, track, and identify travel at a depth between sea level and approximately 500 feet, which narrow slice of the ocean is really all that we are interested in. For the purpose of this discussion, the following ranges for reliable sonar detection have been established:

With passive listening devices, 30 miles in shallow water against noisy targets (such as surface vessels using diesel engines);

With active sonars against quiet submarines, 1 mile.

It must be realized that these ranges of 30 miles and 1 mile may be extended or reduced by the introduction of new techniques in the development of submarines and submarine-detection devices. However, the system can equally well be defined for other ranges if greater or smaller ranges become available.



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The particular areas of interest that were specifically investigated are the areas marked A and B on Fig. 14B-1; i.e., the areas that can, in general, be characterized as the gateway to the Atlantic Ocean between Greenland and the United Kingdom, and

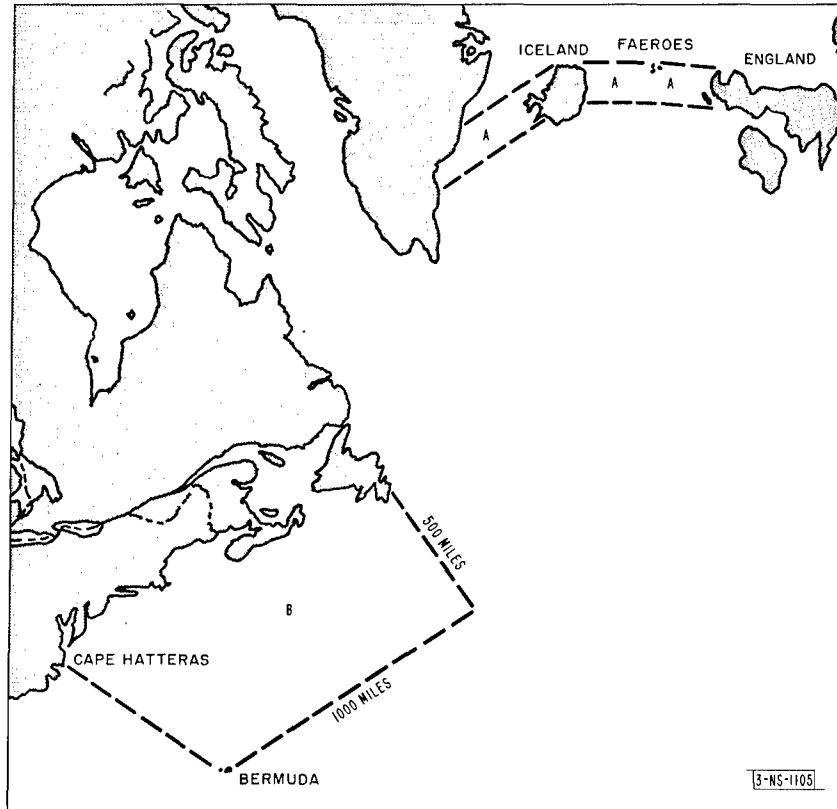


Fig. 14B-1. Atlantic Ocean surveillance areas.

the area immediately adjacent to the east coast of the United States. If we wish to detect man-made objects in these two areas, we must first examine the basic problem—can a number of detection stations so be put into the ocean that all objects passing through Area A will be detected, identified, and tracked, and all objects within Area B will be under continuous surveillance?

A survey of all possible ocean stations indicates that probably the most reliable and presently available equipment for such a system is an anchored buoy. The anchored buoy has successfully been used in shallow water for a considerable number of years and has recently been used in deeper water also. Specifically, the anchored buoy has been used in connection with the following problems:

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Mines and mine field markers,  
General navigational markers and buoys,  
Location markers for specific danger spots (such as the buoys  
used by cable operating and repair companies),  
Research purposes (e.g., wavemeters, etc.).

It is fully realized that anchored buoys have their problems - that they are subject to storm damage; that they require maintenance; and that they can be willfully destroyed. But as a general solution to our problem, i.e., the placing of a "container" in the ocean for the mounting of various types of detection equipment, they appear to be eminently suited.

A typical relatively inexpensive design of such a cable buoy, as used by Western Union Telegraph Company, may be seen in Fig. 14B-2, which shows a fairly large buoy with a 4-ton buoyancy. It has been in use for a number of years, and has been anchored at depths up to 2900 fathoms. It gives generally trouble-free operation, and the only damage appears to occur when it is used in deep water and gets towed under by a heavy current, which causes the buoy to collapse. The cost of these buoys of the general type shown in Fig. 14B-2 was established to be quite reasonable - \$820.00 for the 13-cwt buoy, and \$1488.00 for the 4-ton buoy (F.O.B. Halifax). This indicates the general range of the prices of these buoys, and further details are shown in Table 14B-I. It can be noted from Fig. 14B-2 that these buoys contain a semiautomatic unlatching mechanism, so that the buoy can be picked up in fairly rough weather and the anchoring cable disconnected.

The anchoring of these buoys appears also to be well under control. The various types of anchors, ropes, links and swivels, even at considerable depth, appear to be solved satisfactory. It is not intended to minimize the problem of anchoring objects in deep water, but it should be recognized that this has been done repeatedly, that the technique is reasonably well understood, and that these buoys are presently in use and give satisfactory performance. It is also noted that these buoys are large enough to carry a considerable amount of detection and communication equipment.

The mentioning of this particular buoy in detail does not imply that it is better suited for the purpose than other buoys now in existence, but is intended simply as a typical example of what is presently available. There are many other buoys in existence that may perform the task equally well.

A careful examination of the bottom profile of the Denmark Strait indicates that a route can be found in which the average depth of the strait is approximately 200 fathoms.

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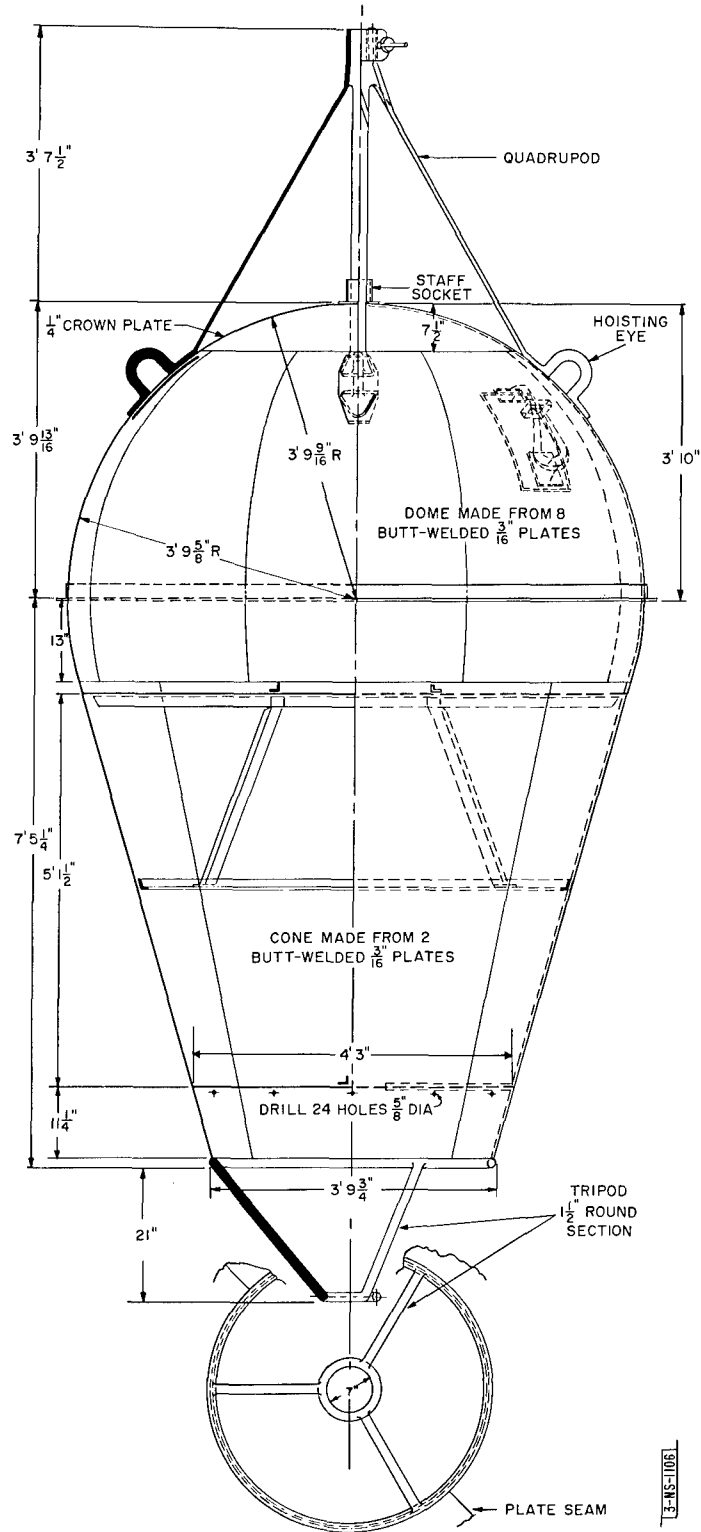


Fig. 14B-2. 4-ton balloon buoy.

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TABLE 14B-I

## COST OF COMPONENTS

Cost of telegraph cable, various thicknesses, armor and insulation: per n. mi. 320 to 1288 pounds sterling (approx. \$900 to \$3,600 per n. mi.)

Cost of 13-cwt buoy: \$820 F.O.B. Halifax, N.S.

Cost of 4-ton buoy: \$1488 F.O.B. Halifax, N.S.

Mushroom anchor for 13-cwt buoy: \$46.00

Miscellaneous swivels and fittings per buoy: \$64.00

Mooring cable, break strength 9 tons, approx. cost: \$1,000 per n. mi.

### Estimate for Cabled Buoy System in Denmark Strait

Initial system, consisting of up to 400 miles of cable, up to 7 buoys, each with string of microphones.

- |                                                                                                                                                  |             |
|--------------------------------------------------------------------------------------------------------------------------------------------------|-------------|
| (a) 7 buoys, equipped with preamplifiers, coolers, etc. estimated price \$8,000 per buoy, including anchor and anchor cable, swivel joints, etc. | \$ 56,000   |
| (b) Lateral cable, about \$3,000 per mi. up to 350 mi.                                                                                           | \$1,050,000 |
| (c) Vertical risers, 7 each, 200 fathoms long                                                                                                    | \$ 5,040    |
| (d) Terminal equipment on land                                                                                                                   | \$ 200,000  |

Approx. \$1,311,040

This does not include estimate for replacement, maintenance, cable-laying ships, installation, spares, development, etc.

### Estimate for Cabled Buoy System Greenland-Iceland-Faroes-United Kingdom

Similar system using one terminal station in Iceland for the Iceland-Greenland cable, one terminal station in the Faroes for Faroes-Iceland cable, and one terminal station in Scotland for United Kingdom-Faroes cable, with buoys placed 40 to 50 miles apart.

Approx. \$4.5 million

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Similarly, the routes between Iceland and the Faroes and between the Faroes and the United Kingdom are also reasonably shallow. Typical profiles of the Denmark Strait are presented in Fig. 14B-3. It appears, therefore, that as far as solving the problem of Area A is concerned, the location of a number of buoys would be a natural solution to the problem, provided that several difficulties can be resolved:

The buoys must be anchored in such a way that they do not provide a hazard to navigation;

They must be located in such a manner that they will not easily be damaged by storm, ice, vessels, or other floating objects.

They must be located in such a manner that they cannot easily be destroyed.

They must be located in such a manner that they can be found and retrieved conveniently for purposes of maintenance and repair.

These requirements appear to be conflicting at first, but it was soon found that most of them can be satisfied by anchoring these buoys at a reasonable depth below the surface of the water. In general, a depth of 20 fathoms was selected, because this provides sufficient protection from normal ocean-going vessels, waves, etc., and still it is not deep enough to require abnormally strong and expensive structural requirements to prevent collapsing of the structure.

The location of these buoys by enemy submarines for the purposes of destruction would be difficult without revealing the presence of the submarines; the probability of accidental collision with submarines is extremely low. However, the buoys can be located for maintenance and repair by means of an internal noise source, which can be actuated from the central communications station; or they can be made to surface or signal either at predetermined times or by means of actuating signals.

It appears, then, that the basic shell for the housing of a detection and communications mechanism can be located below the surface in Area A and give a complete signal whenever an enemy ship or submarine passes. The problem still to be solved is that of communications, for which various possibilities have been considered: (a) radio communications, (b) communication by wire, (c) sonic communication.

For Area A, wire communication appears to be the natural selection, and will give reasonably trouble-free operation. Let us take as a typical example the Denmark Strait between Greenland and Iceland, whose profile is shown in Fig. 14B-3. If, as the first installation, we wish to install a passive listening system with a range of 30 miles, and if we wish to provide a certain amount of overlap, we could place the subsurface

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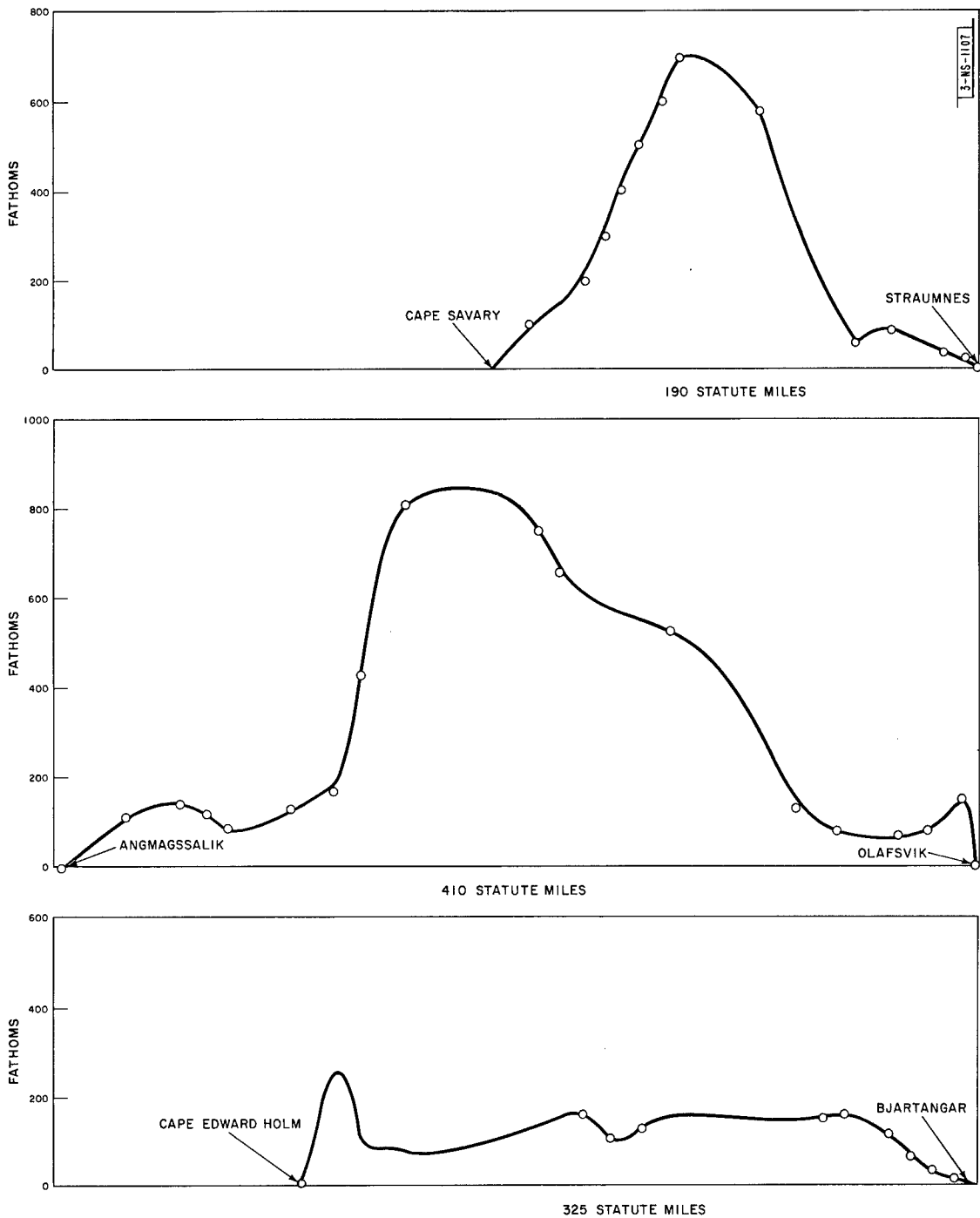


Fig. 14B-3. Various bottom profiles in Denmark Strait.

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buoys at a distance of 40 to 50 miles apart. It can then be seen that approximately 5 to 7 of these buoys would completely cover the Denmark Strait, depending on the particular route selected. These buoys would be connected by a cable (Fig. 14B-4)

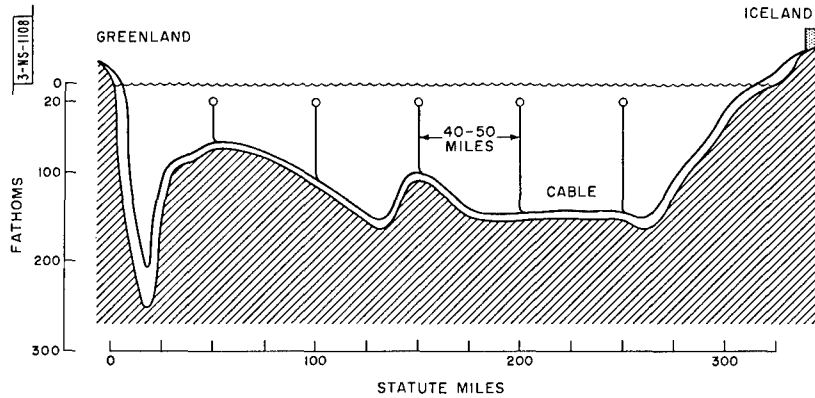


Fig. 14B-4. Denmark Strait cabled buoy system.

that would terminate in Iceland, preferably near one of the radar sites that has already been projected by the U.S. Air Force. The total length of the cable will be approximately 200 to 400 miles (lateral distance), and approximately 5 to 7 lengths of 200 fathoms (vertical risers). The characteristics and cost of these cables are shown in Table 14B-I. Each buoy would contain a series of microphones, located in a string along the vertical-rising anchoring cable to provide greater directivity in the vertical plane. In addition, each buoy would contain a preamplifier and coding device that would permit many buoys to use one cable. These coding devices will, of course, become more complex as the number of buoys increases; but a preliminary investigation of the coding problem indicated that the connection of 5 to 7 buoys on a two-conductor cable (with characteristics as shown in Fig. 14B-5 and -6) would not be too complex, and would require a minimum of equipment. The spacing of the buoys is such that loading coils may be introduced at the anchoring point of each buoy in the cable in order to reduce the capacitance effect of the transmission line. In addition, inductively wound shields, now available on most cables, would permit the continuous loading of the cable. It is believed therefore, that a cable (as previously described) will provide a reasonable communication link for a number of buoys located in Area A.

The terminal station (at Straumnes, for instance) will contain a number of decoders and recorders, as well as provisions for sending power through the cable to the various buoys and for measuring defects in the line if they occur. It may be possible also to include a mechanism that could suppress the output from all the buoys except one, if it is desired to listen to a single set of microphones exclusively.

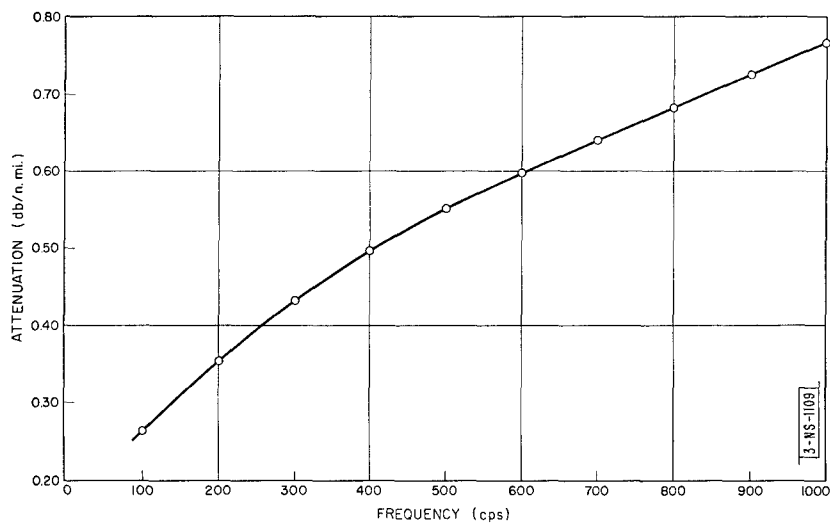


Fig. 14B-5. Typical submarine telegraph cable characteristics in db per n. mi. vs frequency.

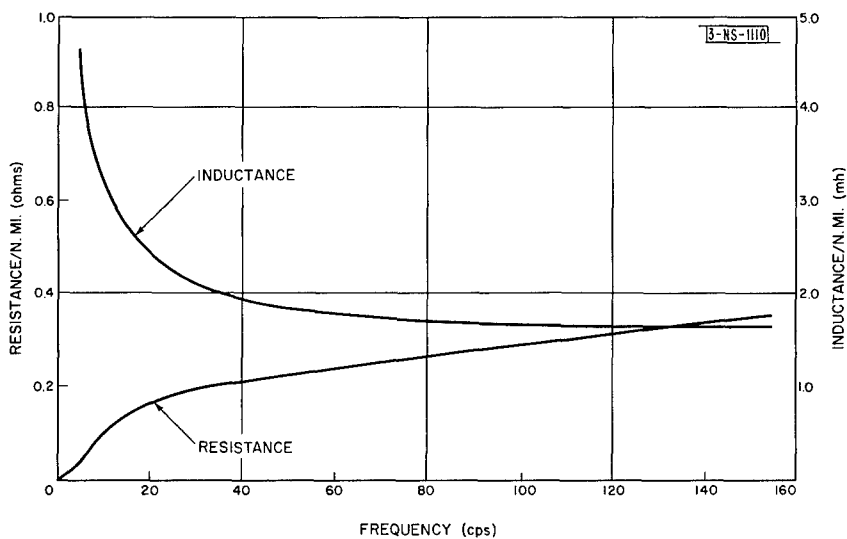


Fig. 14B-6. Typical example of cable characteristics.



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With the development of the quiet submarine, it will be necessary to expand the system to include active sonars, and two significant developments must therefore take place in the cable:

The cables must now be capable of carrying the power for active sonar devices, which is probably an order of magnitude greater than that required for listening devices alone;

The number of buoys is greatly increased because the range of active sonar devices is considerably less, and, as a result, the multiplexing problem becomes more difficult.

However, the interesting thing about this system is its capability of growing gradually. First, the number of buoys can be increased and, consequently, the spacing between the buoys will be decreased. The range requirements thus become smaller, and the possibility of passing undetected becomes proportionately smaller. In addition, various experiments can then be tried as to the feasibility of more complex coding equipment (which would permit the placing of many more listening stations on one cable), or the introduction of a cable having more conductors (which would permit the multiplexing of more listening stations with simpler coding devices).

Next, active sonar systems must be introduced which, in turn, require sonar transmitters. An investigation has been made of the complexity that would be introduced by having a string of active sonars on a single transmission line, powered and synchronized from a land-based source. It was found that the system could be considerably simplified if the transmitters and receivers were placed in separate locations. The sonar transmitters could then be located on a second cable parallel to the first one, but at a distance of one to two miles from the first cable. Timewise, this would simplify considerably the initial development problem, since the separation of the transmitter and receiver eliminates the difficult problem of feeding power to, and receiving signals from, a number of sonars over a single pair of conductors. Such a series of sound-transmitting buoys connected by a cable (Fig. 14B-7) would be both powered and pulsed from the shore station.

The separation of transmitter and receiver has two additional advantages in that, first of all, the multiplexing problem is made considerably simpler; and second, a single set of transmitters can service two sets of receivers located on either side of the transmitting line. Enemy action may cause damage to the transmitters, but, in general, the location of the receivers will be difficult to determine since they do not generate any signals. It is difficult to make a cost estimate for such a system, but an attempt has been made for Area A (see Table 14B-I).

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Some weight has been given, in all these considerations, to a system that can be put into effect immediately and grow gradually as the need arises. It is believed to be of great importance that some detection mechanism, however imperfect, be put into operation immediately. The basic planning for terminal facilities, maintenance crew,

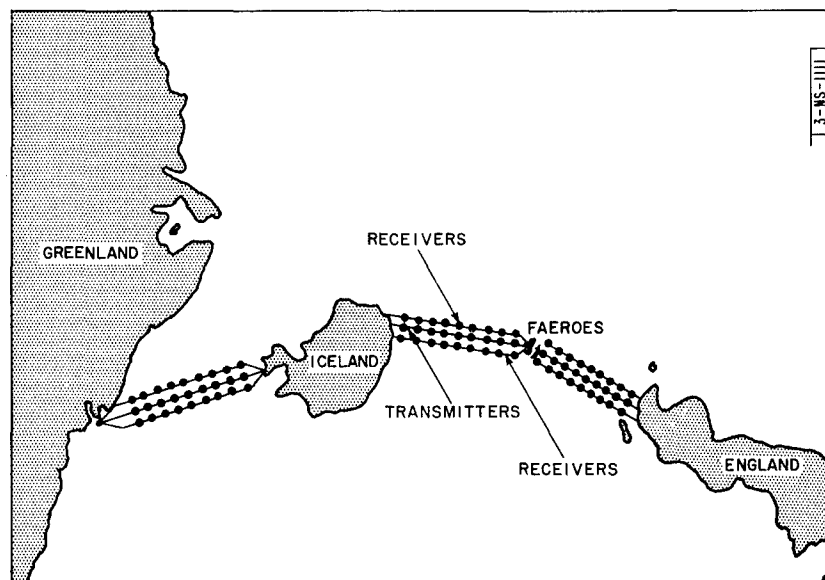


Fig. 14B-7. 3-cable active sonar system for Area A.

support, communication, etc., will not differ radically, whether active or passive sonars are employed 50 miles or 2 miles apart. Consequently, a powerful deterrent is available immediately which might be of real use in discouraging the planning of a submarine attack. A simple line - with 5 to 7 microphones between Greenland and Iceland, 7 to 10 microphones between Iceland and the Faroos, and approximately 8 microphones between the Faroos and the United Kingdom - could be put into effect rapidly, with further implementation of active sonars to be done later.

Whereas the techniques of buoy and cable laying are understood, they should be further aided by additional development. It is suggested, therefore, that existing developments on anchored buoys be expedited and augmented by new developments where necessary. The availability of a stationary subsurface platform to contain electronic equipment reliably is of paramount importance.

Let us now examine Area B in Fig. 14B-1, the eastern approaches to the United States-Canadian mainland. This area, in which close surveillance is required, is approximately 500 by 1000 miles; but the depth of part of the ocean, although fairly shallow

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near the coast, is considerable (2000 to 3000 fathoms). As progress is made in the development and solution of the deep-water anchoring problem, the cables could be placed in an east-west direction, further out from the coast. For passive sonars the cables can be located 50 miles apart, with microphone strings 50 miles apart along the cable. Approximately 20 cables, each 500 miles long, would be sufficient, and terminal stations would be located on the coast.

It is recognized that cables and buoys in coastal waters are subject to various hazards, such as destruction by fishing nets, anchors, towing lines, etc., but it must be remembered that a large number of cables are used successfully in this area at the present time. The addition of vertical risers should not significantly decrease the usefulness of these techniques. The further development of techniques, such as burying the cable by plowing it into the ocean bottom, should be encouraged. (It is understood that this is being done successfully.) Further development of anchoring devices, cables and other facilities should be expedited.

For maintenance purposes, it will be necessary to surface the buoys periodically; this can be done by various means, a few of which are mentioned here:

Electrical unwinding of anchor cable from the buoy, initiated by the land station by means of signals through the cable;

The use of a secondary buoy that is left floating on the surface and which can be used to pull up the underwater buoy;

Grappling of main cable and hoisting it to the surface, which also would lift buoys.

Many other schemes can of course be employed, and it is suggested that this problem be given serious attention.

With the successful development of a stable enclosure that could contain detection and communication devices, additional tools would be placed in the hands of the defense planners. A few are mentioned here briefly, some of which are already under active development:

A series of subsurface buoys connected by a set of cables to a centrally located radio buoy, which would transmit the information obtained by the subsurface buoys (see Fig. 14B-8). Such a unit could be put up anywhere in the ocean;

A surface buoy that would contain a short-range radar, a communications transmitter, and a sonar device; this unit might be either drifting or anchored. Preliminary designs show that a relatively small unit could be built with a radar set having a 30-mile range, a sonar listening device having

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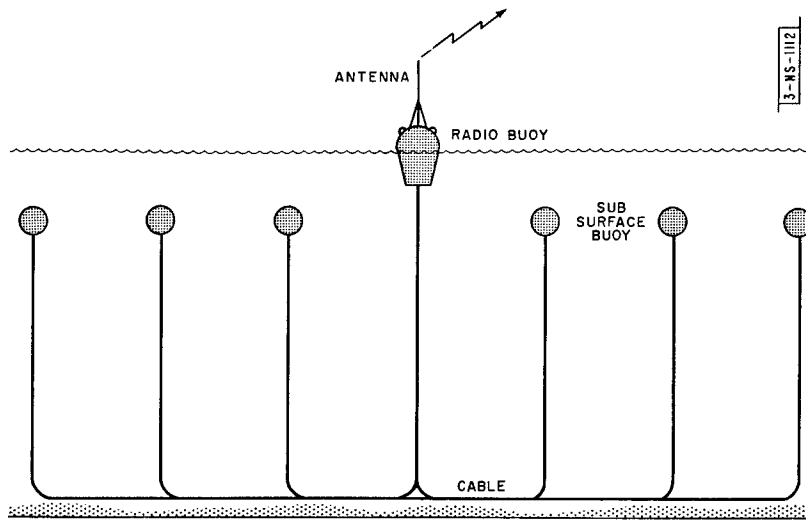


Fig. 14B-8. Radio buoy system.

a similar range, and a long-range communications transmitter and enough batteries to last for 6 months;

A subsurface buoy, either anchored or free-drifting, that would surface periodically to transmit the stored, received sonar information.

*L. Katz*

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## APPENDIX 14-C LONG RANGE ACTIVE SONAR

### INTRODUCTION

The detection, tracking and identification of all sea-borne traffic approaching the North American continent is a necessary part of any comprehensive continental defense system. Chapter 14 discusses a system of sea-traffic control centered around a digital computer which, when fed with data from various sources, would automatically track all targets, identify friendly vessels, point out unidentified targets, and provide a graphical up-to-date picture of the surface and sub-surface situation.

Acoustical devices are important sources of data on submerged and snorkeling submarines. Lofar and similar passive systems as now operating and planned will be valuable sources of information for the next several years at least. Since the quiet submarine defeats passive detectors, we may expect an intense effort by the Russians to quiet their submarines. Therefore, a long-range active sonar is urgently needed. Project Lamp Light discussed the possibility of such a system with several specialists in the underwater-detection field. The consensus was that a determined effort should be made to test its possibilities.

### TECHNICAL FEASIBILITY

It appears possible that an active sonar system, operating at 1000 cps or less and with a maximum range of 30 to 100 miles, could be developed. This conclusion is based primarily on the success of the Lofar system and the recent measurements of R. J. Christensen at the Naval Electronics Laboratory (NEL), San Diego. The Lofar experiments show beyond a doubt that low-frequency sounds travel long distances in the ocean without appreciable attenuation. The NEL measurements show that, in the deep water off the West Coast, the intensity of 1000-cps signals falls off less rapidly than the inverse square of the distance for distances up to 100 miles. This must mean that some of the sound is reflected or refracted back into the water near the bottom and top of the ocean. Christensen believes that in his experiments the sound waves are confined to a "channel" by refraction in a region of minimum sound velocity. This minimum in the sound velocity is the result of temperature and pressure variations with depth.

The following data summarize the NEL experiments:

Frequency	1000 cps
Wavelength	5 feet

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Noise level	- 33 db
Power	108 db (about 1 kw)
Antenna gain	Omnidirectional
Propagation	4 to 5 db for a factor of two in range

The reference intensity level is that corresponding to a sound pressure of 1 dyne/cm<sup>2</sup>. The source power reference is a source providing an intensity corresponding to 1 dyne/cm<sup>2</sup> at one meter from the source. If we assume an effective cross section for a submarine of 100 square meters, we can make a guess at the performance of an active system.

Source power	108 db
Transmission loss for 30 miles (2-way) at 5 db for a factor of two in range	-160 db
Cross section	20 db above one square meter

This gives  $108 - 160 + 20 = -32$  db or just about noise level, which means we have a workable system.

This calculation is probably a little on the optimistic side. The propagation loss in the ocean areas of interest may be far larger than is encountered in the deep water off the West Coast. In shallow water and in deep water where a sufficiently strong velocity minimum does not exist, bottom and surface reflections may introduce large additional losses. The submarine cross section assumed here may be optimistic. Noise conditions may be variable.

However, there are many possible ways to increase system performance. Source intensity can be increased. A 140-db source is being built at Naval Research Laboratory. Sources and receivers used in our calculation are omnidirectional. Improvement could be expected with directional transmitting and receiving arrays. Sophisticated data-processing procedures at the receiver could be profitably employed. The best operating frequency remains to be determined. This optimum frequency is probably less than 1000 cps and depends on many factors including, perhaps, geographical location.

## Large Size and Weight

### POSSIBLE DIFFICULTIES

The large size and weight of equipment necessitated by the requirements for high power and the need for directivity of transmitting and receiving arrays at low

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frequency is certainly a drawback. Shore-based stations would seem to be indicated, at least initially. (In fact, putting a long-range sonar on a moving platform might make the interpretation of the echoes exceedingly difficult.) Some reduction of the size and weight of the equipment may be expected. For instance, it is possible that the transmitter could be made more compact and more efficient by using a purely mechanical system to provide energy directly to the water.

## Difficulty of Interpreting the Echoes

The interpretation of the echoes received is difficult in the high-frequency sonar systems now in use. With a target at 100 miles, it would take about 5 minutes for the primary wave to travel out and the echo to return. There would presumably be many echoes from sea mounts and other bottom features, from temperature and salinity discontinuities, etc. One obvious advantage of the low-frequency system is that the long wavelength employed will markedly decrease return from smaller objects such as fish. If the system will, in fact, detect echoes from submarines, it seems reasonable to expect that some means can be found to sort out the desired signals. At shore installations, permanent echoes could be charted and classified. The use of Doppler effect as a moving-target indicator is probably feasible. The magnitude of the clutter problem will not be known until a system is operating.

## OPERATION UNDER THE POLAR ICE CAP

Submarine operation under the polar ice cap has been made plausible by the development of closed-cycle engines, both nuclear and chemical, and the possible use of bottom-contour navigation. The Russians are known to be extremely interested in the ocean-bottom characteristics in the arctic. Long-range low-frequency sonar operated from the ice cap may be useful in combating this threat. The operation of this system under ice should be studied.

## SUMMARY AND RECOMMENDATIONS

There is a good possibility that a long-range active sonar system can be developed. It is recommended that experiments to test the feasibility of this system be energetically pursued.

*D.T. Stevenson*

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## APPENDIX 14-D DATA FOR PROCESSING SEA SURVEILLANCE

### INTRODUCTION

The U. S. Navy now maintains a plot showing sea traffic in the North Atlantic Ocean and a similar plot for the North Pacific. These plots are useful in the conduct of fleet operations, because timely and accurate information is available on naval vessels (and other ships under U. S. Government control). The plots provide only rudimentary aid to continental defense against sea-borne attack, largely because there is little direct surveillance information on surface and subsurface vessels. This appendix describes a sea-surveillance system designed to provide complete and timely information on all sea-borne traffic within a zone extending several hundred miles from shore. Such a system would provide a basis for effective countering of the sea-borne threat.

The system makes use of a variety of surveillance detectors including air, surface and land-based radar, together with Lofar and sonar equipments. Some of the detection subsystems are designed primarily for air surveillance, and provide sea-surveillance data as a by-product.

The system employs a central data-processing facility that operates only on the sea-surveillance problem. The data-processing center employs a commercially available electronic digital computer to correlate information from the several data sources, and thus provides a complete, accurate and timely picture of all sea traffic. Provision is made also for the dissemination of surveillance information to subsidiary naval commands.

### THE THREAT

The Soviet Union has the capability to modify existing merchant ships or submarines to deliver atomic weapons to the North American continent. Such vessels could carry, launch and control airborne missiles equipped with nuclear warheads, which could be launched a few hundred miles offshore and could be used effectively against coastal cities. These vessels could also be used to mine coastal waters and harbors. Modified merchant ships would be visually indistinguishable from peaceful vessels and, in the absence of defensive measures, they could approach our shores undetected.

Though the magnitude of this threat is less than that of the airborne threat, it cannot safely be ignored. Improvements in our air defense system make the sea attack



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proportionately more profitable to the enemy. Furthermore, simultaneous or coordinated sea-and-air attack might be employed effectively. These factors suggest that defensive measures against both sea and air threats should be developed as parts of a coordinated plan.

Though the threat applies to both the Atlantic and Pacific Ocean approaches, the described system is designed for operation in the Atlantic. With modifications, it would be suitable for the Pacific.

## Objective

**GENERAL DESCRIPTION OF SYSTEM** The surveillance system is designed to detect, identify and track all vessels or floating objects within a region extending 600 to 1000 miles offshore. The surveillance system itself does not include means for taking defensive action against suspect ships; rather, it provides the information necessary for the alerting of defensive naval forces and the direction of sea or air elements to suspect vessels. The way in which surveillance information is used to carry out missions of interception, inspection or destruction will naturally vary from one situation to another.

## Surveillance Coverage

The system is designed to provide complete surveillance within a primary zone (600 to 1000 miles offshore), within which every vessel must be detected and identified. As long as a vessel is within the primary zone, it must be continuously tracked. Ocean areas outside the primary zone constitute a secondary surveillance zone wherein partial surveillance is maintained. Provision is made for tracking naval vessels and friendly commercial ships that voluntarily make periodic position reports. Maintenance of such tracks in the secondary zone facilitates the control of friendly vessels and aids in air-sea rescue operations.

Within the primary surveillance zone, it is important to attain a high detection capability against suspect ships, which is achieved by making use of all applicable sources of information. These include the AEW/picket-ship air-surveillance system, the Lofar system and a proposed land-based ground-wave radar system, which are described in other sections of the Lamp Light report.

## Identification

Three principal identification methods will be employed – procedural, sail-plan matching, and visual recognition.

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Most of the vessels penetrating the primary surveillance zone will belong to friendly nations whose ships should be willing to cooperate in the use of procedural identification methods. Procedural identification makes use of existing marine communication equipment, together with preplanned communication schedules and the exchange of preplanned code words. Such identification will be carried out principally on the picket ships associated with the offshore AEW picket configuration. A penetrating ship will usually be within HF ground-wave communication range of the nearest picket. Probably 80 to 90 per cent of the penetrating traffic should be identified in this way.

When a ship is identified by procedural methods, it is necessary to insure that the identified ship is correctly associated with the corresponding surveillance track. This can be accomplished by taking a DF bearing on the identifying communication. Picket ships and land stations that participate in identification procedures should have the necessary DF equipment.

The matching of surveillance tracks with sail plans constitutes a second identification means. It is used to verify procedural identifications and, when these fail to operate, may be the only identification for friendly ships.

Ships that fail to attain friendly identity by the above means must be intercepted and identified by visual recognition or inspection. It is important that most friendly ships cooperate in the surveillance operations in order that the number of interceptions can be held to a reasonable value.

## Communication and Data Processing

Surveillance data are communicated from the detection subsystems over naval communication facilities to a data-processing center. Teletype transmission is used, and messages adhere to a standardized format.

The data-processing center makes use of a commercially available electronic digital computer to correlate surveillance information and maintain tracks. A brief quantitative study of the data-processing requirements indicates that either the IBM type 704 or the Remington Rand type 1103 computer has adequate capabilities.

Standard format teletype input data will automatically be entered into the computing system. The principal data-processing operations, which will also be carried out automatically, include the initiation of new tracks, the up-dating and correction of tracks, and sail-plan matching. Electronic displays are used for the monitoring of computer operations and the display of surveillance information to command personnel. A large summary display is also provided.

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The computer contains complete and nonredundant surveillance information at all times. This information, properly addressed, is automatically transmitted in teletype form to subsidiary naval commands at periodic intervals. Such commands can thereby maintain up-to-date surveillance plots covering areas of interest.

The use of a general-purpose digital computer at the processing center makes possible the addition of new surveillance-data sources without the procurement of new central processing equipment. Processing procedures can be changed without making equipment alterations by changing the computer program.

## DETAILED DESCRIPTION OF DATA SOURCES

A study was made of the data-collection subsystems that might be operative in the 1960 time period to obtain a quantitative estimate of communication and data-processing requirements. The estimates were further based on an average surface traffic density in coastal waters of one ship per thousand square miles, and an average density elsewhere of one ship per five thousand square miles.\* The density of submarine traffic was assumed to be negligible in comparison with surface traffic. Approximately 3000 ships are assumed to be in the Atlantic Ocean, nearly half of which may be in the primary surveillance zone.

### AEW/Picket-Ship Offshore Surveillance System

An AEW aircraft will detect 40 surface ships per hour in coastal waters, and 8 surface ships per hour elsewhere. From ten to twenty AEW aircraft might be operating and might provide a total report rate of between 150 and 300 reports per hour.

### Ground-Wave Radar

A ground-wave radar with a detection range of 400 miles and sector coverage of 180° might see about 100 surface targets. If ten such stations are reporting at two-hour intervals, the total report rate is 500 reports per hour.

### Voluntary Communication

Most of the friendly ships at sea should be willing to make periodic position reports at intervals of perhaps 6 hours. These could be made by normal communication facilities or, at a future date, might be made by an automatic transponder system. The total report rate might be 200 reports per hour.

\*Data taken from "Development of World-Wide Air Surveillance System," Joint Air Defense Board, Report JADB-21 (23 April 1954) (SECRET). Figure 13-5, "Map of Atlantic Shipping," shows the distribution of ships on 1 May 1952.

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## Lofar Evaluation Centers

A Lofar evaluation center may be expected to make 30 reports per hour. Ten such centers would have a total report rate of 300 per hour.

## Other Sources

The system will also be supplied data, at considerably lower rates, from several other sources which may include Movement Report Offices, MATS and commercial aircraft, fleet elements, patrol aircraft, surface shipping, HF/DF, harbor shipping control offices, and intelligence agencies. The total from such sources should not exceed a few hundred reports per hour.

## Summary of Input-Data Requirements

The total amount of input data to the data-processing center should lie between 1000 and 1500 reports per hour. A rate of 1200 reports per hour has been chosen as a reasonable design number.

## COMMUNICATIONS

Each of the principal data-collection agencies is assumed to transmit its information to the data-processing center over standard naval communications facilities. Teletype communications would be employed, and messages would adhere to a standardized form. To simplify communication requirements, each agency will probably follow a fixed communication schedule that requires the transmission of a message every one or two hours. A typical message would contain the addresses necessary for message routing and the identification of the data source, followed by a list of surveillance reports (target information) pertaining to the sightings made since the previous message. Each surveillance report would contain latitude, longitude, course and speed (if available), time of fix, and identity (if available). Each report would require about 30 teletype characters. The message from a typical station might include 50 reports, and might require 3 to 5 minutes' transmission time.

## Description of Computer

### DATA-PROCESSING CENTER

The data-processing center makes use of a general-purpose electronic digital computer, which may be either the IBM type 704 or the Remington Rand type 1103. Two computers are used; one is actively engaged in surveillance data processing, while the other is undergoing maintenance or is on stand-by.

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Figure 14D-1 is a block diagram of the computer (the IBM type 704 is the example chosen). Data enter the computer in two ways. First, standard format teletype messages are perforated on punched teletype tape, then transcribed into magnetic tape. The speed of the paper tape to magnetic-tape converter is 500 teletype characters per second; thus, a single unit can transcribe all input data. When the magnetic tapes

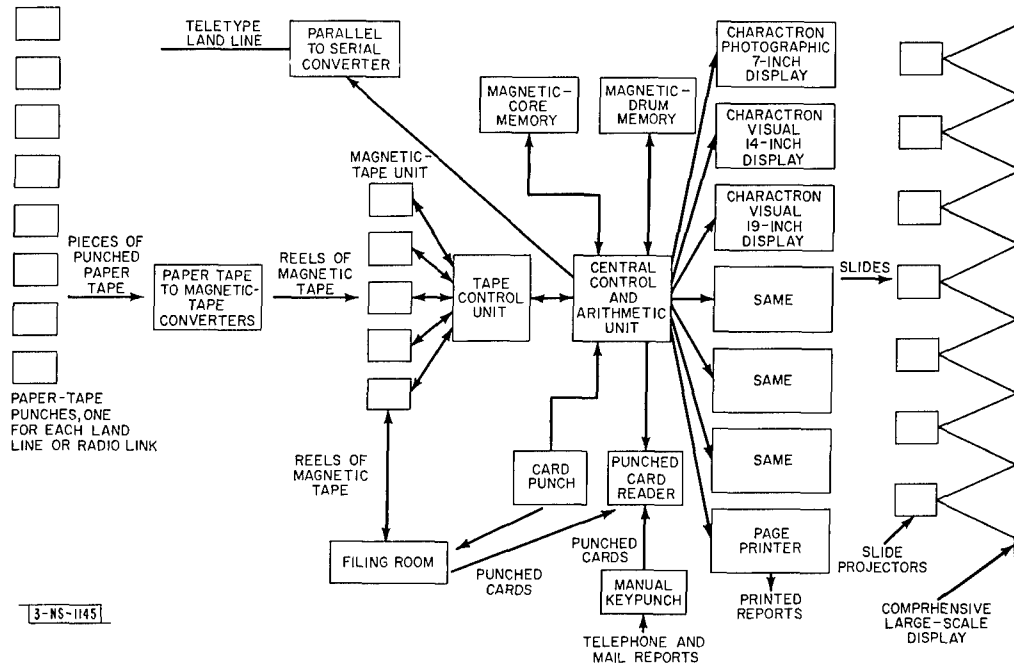


Fig. 14D-1. Data-processing equipment and flow of information (showing one of two calculators).

are placed in the computer-tape units, the recorded information is accessible to the machine. A punched-card input allows the introduction of other data, and may consist principally of nonstandard data received by voice or mail transmission. Information is stored in the computer in terms of computer words, each of which contain 36 binary digits and is equivalent to about 7 teletype characters.

The magnetic-tape units are one of several types of storage used in the computer. Each tape unit stores about a million computer words of 36 bits each, and this information can be transferred to the computer at a rate of 15,000 teletype characters per second. The magnetic tapes are used to store large amounts of information that are used relatively infrequently. The magnetic-drum memory stores 8000 words, and two such memories may be used. Transfer of information between the drum memories and other computer units occurs at a rate of 10,000 words per second. The magnetic

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drums are used to store smaller amounts of information that are consulted more frequently. The magnetic-core memory is a very-high-speed storage for 4000 words. It communicates with the control and arithmetic units, and the transfer of a word requires only a few microseconds.

The control and arithmetic units govern the flow of information throughout the entire computer, and perform the arithmetic computations essential to the data-processing operation. The behavior of the entire computer is governed by a program consisting of instruction words, which may be stored in any of the various memory units. The IBM 704 computer performs arithmetic computations at high speed, a single addition requiring 24  $\mu$ sec.

Electronic displays are connected to the computer to provide visual data outputs for monitoring data-processing operations and for display of output surveillance. The Charactron display units are not a part of the IBM type 704 but are made by Convair, and are suitable for connection to the computer. The display units show surveillance data on a large cathode-ray tube. Each ship is represented by a vector that indicates the ship's relative position, speed and course, and beside each vector are four characters of identification information.

A keyset is associated with each display. The display operator can use the keyset to interrogate the computer, requesting the particular type of information he wishes to see. Thus, the operator might request a display of all unidentified ships, together with all U. S. Navy vessels. The time required for the computer to respond to a display request is about 0.02 second, and about 10 per cent of the computer capability is required to service all displays.

A projection summary display of the entire ocean area is maintained, and is generated by periodic photographing of a smaller electronic display tube, followed by the projection of the photographic slide. The rapid photographic projection system is being developed by the Polaroid Corporation for use in the SAGE System. Only a one-minute time delay is encountered in the photographic process.

Additional computer outputs consist of a page printer for making printed reports, and a teletype output for sending data to remote locations.

Each IBM 704 installation occupies a room 35 by 50 feet. A separate room should be provided for the display system.

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## Processing Operations

The processing operations are best explained by considering the four types of organized information that the computer stores. The computing processes can then be regarded as the procedures necessary to maintain the stored information up-to-date and properly organized.

Ships'-Characteristics File:- This is a catalogue of descriptive information on all ships, including data on physical characteristics (underwater sound generation, radar cross section, etc.), ownership, registry, and pertinent history of past operations. This information is of use in identifying ships of questionable identity or intent. The information is stored on magnetic tape, and it is consulted fairly infrequently. Data on about 12,000 ships will be stored. About 1000 characters per ship are required, and the total file will occupy two reels of magnetic tape.

Sail-Plan File:- This file is in two parts. The first is a catalogue of sail plans for friendly ships, the second, a catalogue showing the whereabouts of suspect ships. Sail plans for friendly ships originate in port authorities, diplomatic offices, shipping companies, and governmental maritime agencies. A typical sail plan may include time and place of departure, ETA for ports of call, expected routes, information on ship's communication schedule, and code words or procedures to be used for identification.

Data on suspect ships may originate in intelligence agencies, in addition to the agencies that supply data on friendly ships. Data on suspect ships will be much less complete than on friendly ships, and may often be limited to knowledge of the last port of call.

The principal use for sail-plan data is to assist in the identification of ships as they enter the primary surveillance region. Information on suspect ships might occasionally be a basis for the alerting redeployment of surveillance sources, or for the scheduling of special surveillance missions.

The sail-plan file is consulted much more frequently than the ship-characteristic file, and is stored on magnetic tape. Data on about 3000 ships will be stored on magnetic tape.

Established-Track File:- This contains the position, course, speed and identity of all ships, floating hazards to navigation, or other surveillance. Each track is brought up-to-date promptly as new reports are received, and is periodically brought up-to-date by dead reckoning when too long a time intervenes between reports. The established-track data are the principal outputs of the processing system, for they alone provide complete and nonredundant information on all vessels in the defended

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area. They provide most of the data for summary plots, and for broadcast to subsidiary commands.

The established-track file may be consulted many times per second, and is stored on a magnetic drum. About 2000 established tracks may exist typically at one time. Each track requires 4 computer words; thus, one drum-memory unit of 8000 words is required for this information.

Uncorrelated-Report File:- Most new reports that enter the system will quickly correlate with established tracks and will be discarded. Reports that fail to correlate are stored until they can be explained satisfactorily. The uncorrelated-report file is stored on magnetic tape. It is difficult to estimate the average number of uncorrelated reports that may exist, for this depends upon the accuracy and false-report rate of the detection subsystems, and upon the error rate of the communications.

Consider now the processing operations required to keep the files up-to-date. Maintenance of the sail-plan file and the ship's registry is very simple. The principal remaining operations are as follows.

Up-Dating and Correction of Established Tracks:- By making use of course and speed data, the positions of established tracks will be up-dated about once per hour. The track information on cooperating ships will also be corrected periodically as these ships voluntarily report their positions, courses and speeds. The positions, courses and speeds of uncooperating ships will also be corrected periodically by applying correction formulas, which make use of the surveillance reports.

Correlation of Surveillance Reports:- As new reports enter the system, they are compared with each established track. The comparison attempts to associate the reported position with the established track position. If velocity or identity data are included in the report, these are also compared. If association with a cooperating ship occurs, the report is simply discarded. If association with an uncooperating ship occurs, the report is used for track correction, and then discarded.

Variable time delays are encountered between the sighting of a ship by a detection subsystem and the processing of the report in the computer. Each report contains the time of sighting so that these delays can be accounted for. As each report is compared with an established track, the track must first be back-dated to correspond to the time of the report.

Initiation of New Tracks:- The reports that fail to associate with established tracks may be false reports (noise), or they may indicate vessels not previously



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detected. The computer accumulates such reports and attempts to fit tracks to unexplained report sequences. Where tracks can be fitted to the reports, new established tracks are generated and the reports are subsequently discarded. When track fitting fails, the reports are classed as noise and discarded.

The precise criteria for establishing a new track cannot be specified without considerable study and experiment. The criteria should certainly involve the consistency of the surveillance reports and the apparent velocity of the moving object.

Track Cancellation:- Tracks will have to be canceled as ships leave the surveillance zone, as floating objects disappear, or if surveillance is lost. For each established track, the computer should maintain a record of the time since the last report was received. If this time exceeds a predetermined value, the track should be displayed to an operator who can examine the situation and take appropriate action. He might decide to let the track continue by dead reckoning, to cancel the track, or to take some other action.

Sorting Operations:- Most of the operations described above can be carried out most efficiently if the information files are organized on a basis of fixed ocean sectors (perhaps  $10^\circ$  on a side). Periodic sorting operations are required to maintain the sectorized organization of the established-track file, the uncorrelated-report file, and the new reports entering the system.

Display Operations and Teletype Output:- Three types of display operations are envisaged. Some displays will be used for routine monitoring of computer operations, in which cases the display may be generated without operator action; the computer may then halt and await an operator decision. A second type of display is initiated by operator request - i. e., the operator indicates on his keyset which of several sets of rules he wishes the computer to follow in constructing his display. Such operator requests cannot be anticipated in time, and the computer program must make a periodic test of such displays to see if action is required. The photographic output and the teletype output can operate on a periodic basis (about one hour).

## Flow Diagrams

The computer is visualized as carrying out the principal data-processing operations in a series of steps that repeat at intervals of 30 minutes to one hour. The principal operations and the flow of information for each step are shown in Table 14D-I. While each step is carried out, the computer is time-shared between the indicated process and the construction of requested displays.

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TABLE 14D-I			
COMPUTING PROCESSES			
Step	Data Sources	Operation	Result
1	Input data on teletype tape	Transcription	Input data on magnetic tape
2	Input data on magnetic tape	Sort by ocean area	Input data on magnetic tape
3	Sorted input data, established tracks	(1) Adjust track to time of report (2) Correlate by position, velocity and identity (3) Record uncorrelated reports (4) Correct established tracks	(1) Corrected tracks (2) Additions to uncorrelated report file
4	Established tracks	(1) Up-date by dead reckoning (2) Sort by sector (3) Test for staleness	(1) Up-dated tracks (2) Display of stale tracks
5	Uncorrelated reports	Track initiation	New established track
6	Established tracks	Transfer data	Revised photographic display
7	Established tracks	Transfer data	Teletype tape for transmission to subsidiary commands

## Periodic and Special Reports

A significant by-product of the data-processing equipment recommended in this report is a capability to produce high quality, comprehensive, periodic and special reports at very low cost. The reason for this is that general-purpose stored-program computers have been employed which can be used with different programs to do quite different work. One of the significant recent developments in commercial accounting and business records is the use of machinery of this same general sort to reduce the cost and increase the quality of reports and analyses. The same techniques can be used to advantage here.

Magnetic tape would be used to record all information as it developed. All established tracks could be recorded several times a day, and all specific reports – such as sailing plans and intelligence reports – would be recorded. A single reel of tape would contain nearly a million 36-bit words that can be read at the rate of 2500 words per second; therefore, it would be practical to record enough information on tape to be able to go back in time and reconstruct any wanted bit of history.

Example:- Daily or weekly reports could be issued covering the location of all enemy shipping. One form that the report could take would be a book, which could be printed at the rate of three pages a minute, and which would list each ship and relevant facts

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about it. The calculator could be arranged to print headings, page numbers, etc., so that the report would be in finished form as it came off the calculator. It could be printed with four carbons, or so printed as to be reproducible by multilith or any of several other common methods.

The sequence of events in preparing such a report would be as follows.

Put the instructions for this report into the machine. These instructions would be recorded on a small deck of punched cards, and it would take a minute or so for the operator to feed them into the machine.

Put the sail-plan tape of suspects on the machine.

Push the start button for the machine to do the analysis and print the report. It would probably be able to do all the tape reading and the analysis in its spare time while printing, and would thus prepare the report at the rate of 150 ships per minute.

When the machine is done, an operator would remove the report from the machine, assemble the pages, staple them, and put them in the outgoing mail basket. The report, as printed by the machine, would be dated and would contain the title pages, distribution list and other standard items, as well as the basic information on enemy ships.

If desired, the machine could also print, on a map of the North Atlantic, a spot in the approximate location of every enemy ship. The map could be a Mercator projection (covering latitude 10° N to 70° N and longitude 0° W to 90° W, measuring 12 by 18 inches), and would locate each ship to within one-quarter degree (i. e., about 15 miles). To print this report would require about 3 minutes to set up and about 1 minute to print.

If it were suddenly decided that a report was needed describing the travels of 300 ships, printing on a few pages every port each ship had put in at during the past year and the dates of its stay, this could be done quite easily. If no such report had ever been prepared before, a person would have to be put to work to prepare instructions for the machine, which might take a week or two. If such a report had been prepared before, this step could be skipped. Then the year's accumulation of relevant tapes would be run through the machine, requiring hours or days, depending upon just how the records were kept. The actual printing would not take long, and if the necessity for such a report were foreseen, the records could be set up to make it even easier.

In planning, it is helpful to be able to analyze historical records of this sort. For example, if changes were planned in the deployment of picket ships, it would be possible to analyze the records to see how much shipping would pass within what range of each proposed station.

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In analyzing the performance of any data-collection method, the calculator would be invaluable. The machine could be set to compare the detection range actually achieved on a variety of vessels in a variety of weather conditions over a long period, with the standard that should be achieved. It might even be desirable to run a weekly check on this to see that all the radars, etc., were being properly maintained and manned.

Incidental work of this sort would not have to interrupt the main job of surveillance. Two computers have been recommended, and one could bear the load while the other was being given its scheduled maintenance. Most of the time, of course, both machines would be in running order and available; one could carry the surveillance load, while the other was being used to prepare periodic or special reports.

Reports of this sort would not only be cheaper and more accurate than manually prepared reports, but they also would be available much more promptly. Modern business practice demands the use of such machinery in comparable situations, and it is only reasonable to expect that it would be greatly helpful here.

## EFFECTIVENESS AGAINST SUBMARINES

In the preceding sections, no distinction has been made between the surveillance of surface ships and submarines. From the standpoint of data processing, the system requirements are fixed by the expected surface-ship density and the amount of ocean area involved. Most of the detection subsystems (e. g., AEW radar, Lofar, DF, etc.) are effective against both ships and submarines, and can be expected to provide information on both types of vessels.

The submarine surveillance capabilities of the system are greatly enhanced by combining in a single system the data from all sources. A submarine that alternately surfaces and submerges is sensed alternately by different detection subsystems. The system is designed to maintain a smooth and continuous track under these circumstances, and the identity of the submarine is preserved even though the source and type of information changes. Such a system should provide an effective basis for the deployment and control of hunter-killer groups.

*J.E. DeTurk*

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**CHAPTER 15**  
**AIR DEFENSE SYSTEMS AND THEIR EVALUATION**

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## CHAPTER 15

### AIR DEFENSE SYSTEMS AND THEIR EVALUATION

#### INTRODUCTION

The basic threat against North America assumed for evaluation of air defense systems, components of systems, and doctrine was based upon the National Intelligence Estimates. Variations of this threat, including much greater threats and smaller ones, were considered.

The defenses considered were those now existing, those which Continental Air Defense Command has proposed for future development, and variations of these – some relatively minor and some so extensive as to be practically new systems. Consideration of radical changes in general concept did not seem to be justified.

The air defense systems considered were examined by the Evaluation Group in three ways:

A series of map exercises covering several possible enemy attack plans, selected so as to cover the field geographically, in magnitude and as to intended accomplishments;

A mathematical analysis, using a mathematical model of air defense designed to provide a cost vs effectiveness measure for the different defense systems under various enemy attacks;

A qualitative examination of the defense systems to determine factors that could not be answered by the two methods above, such as the reasonableness of the rules of engagement which must be established for the proper operation of the system.

The combinations of circumstances, situations, contestants and other factors that determine the suitability or lack of suitability of a combination of means and plans for defending a large part of the world against air attack are infinite. No formula or computing device was invented by which a correct or best means or system, among any number proposed, could be absolutely determined. Parts of the evaluations of systems and subsystems were accomplished by mathematical techniques. All parts were open to and subjected to argument. Systems were checked by asking specific and pertinent questions regarding them as to various characteristics and with relation to various criteria. Several assumed plans of enemy attack were progressively superimposed on the various defense systems proposed, and the degree of adequacy or inadequacy of each system was progressively judged thereby. Decisions were finally made by a process of judgment after consideration of these checks and analyses. These decisions are reflected in conclusions following this chapter and throughout other chapters and appendices of this report.

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Defense against intercontinental ballistic missiles – a major and radically different problem outside the Lamp Light field of study – was not included in this evaluation. Utilization of nuclear propulsion could allow the enemy more flexibility in planning attacks and, with the same numerical force, enable him to tax the defenses more heavily, but it would not necessarily change the general method of defense.

## MAP EXERCISES

One of the best methods of evaluating a system of air defense is to assume the position of the enemy and, in this role, study the possibilities of making successful attacks through the defenses. Several such attacks were devised and actually plotted on the map; the defenses were evaluated step-by-step as the attacks progressed along the various routes selected. Such tests were conducted as games in which one team commanded and maneuvered the offensive forces step-by-step while the other team commanded and maneuvered the defense forces to check the offense. The defenders were given information regarding the enemy, as it might become available during the progress of such a real operation. Some of these games are described in greater detail in Appendix 15-A.

Obviously, analyses such as these could not be made with mathematical exactness. Operations were, however, run on time and distance schedules and were consistent with assumed aircraft and weapons performance. Assumptions as to probability of detection, identification, interception and kill were necessarily somewhat arbitrary but, wherever possible, factors based on experience were used.

These analyses were quite useful in visualizing problems of maneuvering forces within the defense systems and in judging combat between small numbers of opposing forces. It was not possible, however, to judge the outcome of battles between larger forces, and such battles were analyzed mathematically. These battle analyses are discussed in the following section.

A number of useful conclusions drawn from the map-exercise program are summarized in Appendix 15-A.

The major conclusion was that the needs of Strategic Air Command for warning and defense are satisfied by both the Lamp Light system and the ADR 54-60 system. If plans to speed up SAC evacuation and to increase SAC readiness are implemented, the warning afforded of any attack in force is sufficient to assure SAC of the ability to retaliate in adequate strength. If plans to further disperse SAC are implemented, any attack likely to penetrate by stealth will be insufficient to destroy any serious fraction of SAC's retaliatory strength. These conclusions followed, not only from the map-exercise

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program, but also from a careful comparison of the warning depths provided with stated SAC requirements.

Another major inference drawn from the map exercises was that, against strong defense systems, a concentrated attack is desirable from the enemy's point of view and hence is the most important type of attack to consider in estimating defense-system combat effectiveness.

## MATHEMATICAL ANALYSIS

The objective of the mathematical-evaluation procedures was to assess on a useful quantitative scale the combat effectiveness of various defense systems submitted for evaluation by the Lamp Light Systems Group. In particular, quantitative assessment of the Basic Lamp Light System and some of its variations (see Chap. 12) was desired to establish an effectiveness-cost trend for this type of defense system. This effectiveness-cost curve is of interest in its own right, and is necessary to provide a reference for assessing the increase in defense system capability provided, for example, by the addition of facilities for a remote air battle (see Chap. 13, Sec. II). It also provides a basis of comparison between the ADR 54-60 system and the Lamp Light systems.

The procedures used were designed to take into account, in so far as they are understood, the interactions between the various stages of the air battle. From an evaluation point of view, interest is focused on the contribution of each subsystem to the effectiveness of the over-all defense - not on the less-realistic question of the defense afforded by one of the subsystems all by itself.

### The Target System

The set of aiming points with associated values considered as the target system for the quantitative evaluation was based on urban population. One or more aiming points were assigned to each metropolitan area having a population greater than 100,000 (1950 census). Canadian as well as U.S. cities were included. With three exceptions, a single aiming point was assigned to each city on this list. The exceptions, significantly larger geographically than the other cities on the list, are New York City (3 aiming points), Chicago (2 aiming points) and Los Angeles (2 aiming points). A point value was assigned to each aiming point equal to its 1950 metropolitan area population in millions, rounded off to the nearest 0.1 million. The total point value of the cities having multiple aiming points assigned was divided evenly among the aiming points. The resulting set of aiming points with associated values is given in Table 15-I.

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TABLE 15-1					
TARGET SYSTEM					
Aiming Point	Value Assigned	Aiming Point	Value Assigned	Aiming Point	Value Assigned
*New York (A)	4.1	Winnipeg	0.4	*Reading	0.2
*New York (B)	4.1	*Dayton	0.3	Peoria	0.2
*New York (C)	4.1	Fort Worth	0.3	Little Rock	0.2
*Philadelphia	3.0	Omaha	0.3	*Erie	0.2
*Detroit	2.7	*Hamilton	0.3	Shreveport	0.2
*Chicago (A)	2.5	*Hartford	0.3	Knoxville	0.1
*Chicago (B)	2.5	*Youngstown, Ohio	0.3	*Binghamton	0.1
*Boston	2.2	*Albany	0.3	Duluth	0.1
San Francisco	2.0	Oklahoma City	0.3	Charlotte	0.1
Los Angeles (A)	2.0	*Wilkes-Barre	0.3	Ft. Wayne	0.1
Los Angeles (B)	2.0	*Syracuse	0.3	Calgary	0.1
*Pittsburgh	1.5	*Quebec	0.3	Baton Rouge	0.1
St. Louis	1.4	Nashville	0.3	*Evansville, Indiana	0.1
*Cleveland	1.4	*Richmond	0.3	El Paso	0.1
*Montreal	1.3	*New Haven	0.2	Austin	0.1
*Washington, D.C.	1.3	Jacksonville	0.2	San Bernardino	0.1
*Baltimore	1.2	*Bridgeport	0.2	*Lansing	0.1
*Toronto	1.0	*Scranton	0.2	*Waterbury	0.1
Minneapolis	1.0	*Ottawa	0.2	*Charleston, W.V.	0.1
*Milwaukee	0.8	Salt Lake City	0.2	Fresno	0.1
*Cincinnati	0.8	*Grand Rapids	0.2	Savannah	0.1
*Buffalo	0.8	*Allentown	0.2	*New Bedford	0.1
Houston	0.7	*Worcester	0.2	*Schenectady	0.1
Kansas City	0.7	Phoenix	0.2	*New Britain	0.1
New Orleans	0.7	Sacramento	0.2	Corpus Christi	0.1
Seattle	0.6	Tulsa	0.2	Rockford, Illinois	0.1
*Providence	0.6	Des Moines	0.2	Columbia, S.C.	0.1
Dallas	0.5	*Flint	0.2	Charleston, S.C.	0.1
Vancouver	0.5	Davenport	0.2	Columbus, Ga.	0.1
Portland	0.5	Wichita	0.2	*Fall River, Mass.	0.1
Atlanta	0.5	Trenton	0.2	*Utica	0.1
*Indianapolis	0.5	*Wilmington	0.2	St. Petersburg	0.1
Denver	0.5	Mobile	0.2	*Portland, Maine	0.1
*Louisville	0.5	Tampa	0.2	Stockton	0.1
Miami	0.5	San Jose	0.2	*Lawrence, Mass.	0.1
San Antonio	0.4	Spokane	0.2	Madison, Wis.	0.1
Birmingham	0.4	*Canton	0.2	Montgomery	0.1
*Columbus, Ohio	0.4	*Stamford	0.2	*Roanoke	0.1
San Diego	0.4	Edmonton	0.2	*Lowell	0.1
*Rochester	0.4	*Harrisburg	0.2	*Wheeling	0.1
Memphis	0.4	*South Bend	0.2	*Saginaw, Mich.	0.1
*Norfolk	0.4	Chattanooga	0.2	*Atlantic City	0.1
*Akron	0.4	Tacoma	0.2	Victoria	0.1
*Toledo	0.4	*Huntington	0.2	Jackson, Miss.	0.1
*Springfield, Mass.	0.4				

\*Starred points are in heartland.

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The choice of a representative target system based on urban population was made after it had been ascertained by map exercises that the defense systems under consideration would succeed in making the Strategic Air Command retaliatory force an unprofitable target for the enemy.

The target system chosen for use is, of course, dominated by the heartland; 70 of the 133 aiming points with 47 million out of the total of 70 million people on the value scale lie in this compact area.

## The Effectiveness Index

Defense systems of the kind considered here have an important characteristic exemplified by the curves of Fig. 15-1. They exhibit a marked threshold on breaking-

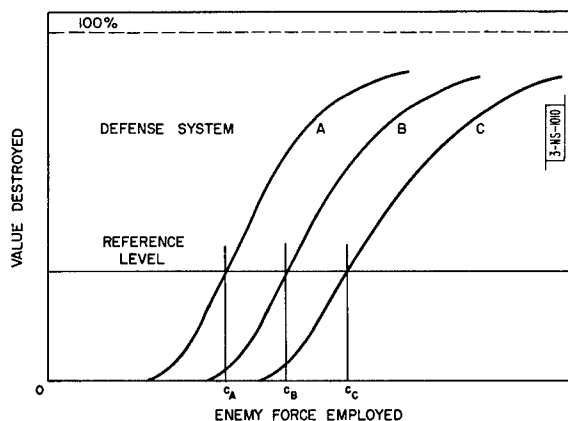


Fig. 15-1. Typical defense system characteristics.

strength effect with respect to the size of the enemy force brought to bear against them. Attacking forces smaller than a certain critical size, characteristic of the defense system under consideration, will be liquidated without achieving significant damage to the target system. However, relatively small increases in enemy force above this critical level result in a large increase in the expected damage. Because of this characteristic, a useful figure of merit for this kind of defense system is the enemy force that must be

brought to bear to bring the damage to some convenient reference level such as that shown in the figure.

For the target system considered here, 100 per cent damage in an attack on the heartland would correspond to 47 million expected deaths. A convenient choice for reference level is 15 million deaths. The figure of merit, or effectiveness index, used in the evaluation is the enemy force that must enter the defense system to produce an expected damage of 15 million deaths from bombs on target. The effectiveness index is measured in units of bomber-type aircraft.

This kind of measure of effectiveness has a number of advantages. Not the least of these lies in its facing squarely up to the fact that any defense can be broken – the relevant question being what it takes to do it. Another important advantage is in

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providing a measure of effectiveness for the defense system that is independent of guesses of the enemy's future numerical strength.

## Design of Enemy Attacks

The process of determining the effectiveness index of each of the defense systems analyzed hinged on the design of an optimal enemy attack against each system considered. Enough hypotheses were laid down in the form of enemy rules to describe in broad outline the kind of attack under consideration. Relatively refined mathematical techniques were developed to design, within this framework, an optimum enemy attack to produce an expected damage of 15 million deaths. Here an optimum attack is one requiring the fewest bomber-type aircraft entering the defense system. This minimum number of bomber-type aircraft required to give an expected damage of 15 million deaths is, by definition, the effectiveness index.

The enemy rules for the attacks on the 1960 systems are as follows. The units of the attacking force are subsonic jet bombers. Each unit of the attacking force carries either a multimegaton bomb, or 3 long-range decoys, or 9 short-range decoys. The bombs are contained in 100-mile-range air-to-surface missiles - Mach 2 for high-altitude attacks, or Mach 0.9 for low-altitude attacks. The decoys, when used, are presumed to be indistinguishable by radar from the bomber-type aircraft that they accompany. The long-range decoys are given a range of 1000 miles; the short-range ones, 100 miles. Active jamming is used whenever it is profitable. Coordination achievable in a massed attack is approximated by a block 50 miles wide extending 250 miles along the path of attack. Within this space there is ample room for Ding-Dong-proof dispersal of the attacking units, that is, a pattern in which a small-yield atomic warhead can be expected to get no more than one kill. Bombs and decoys are assigned to specific aiming points before the attack enters the defense system. The attack is designed to give the expected 15 million deaths from direct effects of bombs on target; any additional damage due to delayed fall-out will be regarded as a bonus to the enemy. Finally, it is assumed that the enemy is well informed about the deployment, capabilities and operational doctrines of the defense.

The sequence of stages of the battle in which the enemy is to use these capabilities is as follows:

Attacking force approaches remote air battle zone and launches first-stage decoys,  
Remote air battle,

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Enemy force approaches far-contiguous (medium-long-range) interceptor battle zone and launches second-stage decoys,

Enemy force enters near-contiguous (medium-range plus medium-long-range) interceptor battle zone,

Enemy force approaches local surface-to-air missile defenses and launches air-to-surface missiles and third-stage decoys,

Bombs surviving the local defense battle are released on target.

The optimization of the enemy attack within these outlines involves the choice of which aiming points are to be attacked, the allocation of the initial attacking force between bomb carriers, first-stage decoy carriers, second-stage decoy carriers, and third-stage decoy carriers, and the briefing of bombs and decoys for specific aiming points. The mathematical procedures used to do this are described in Appendix 15-B.

Estimates of defense performance parameters, such as probabilities of kill, used in the quantitative analysis were agreed on jointly by the Systems Group and the cognizant component group in each individual case. A determined effort was made to make these estimates as realistic and as mutually consistent as possible. The values agreed upon and used in the computations presuppose vigorous action on counter-countermeasures, low-altitude AI radar, low-altitude surface-to-air missile capability development, and improved acquisition for surface-to-air missiles against air-to-surface missiles.

## Effectiveness vs Cost Results for the Contiguous Combat Systems

The Basic Lamp Light System and its scaled-up and scaled-down variations are represented by three points on an effectiveness vs cost curve for a family of defense systems based on the Lamp Light contiguous combat philosophy. The central case for evaluation of the 1960 systems (the Basic Lamp Light System of Chap. 12) presupposes the enemy use of decoys as described above and an anti-air-to-surface missile capability for the surface-to-air defense missiles. The results for this central case are shown in

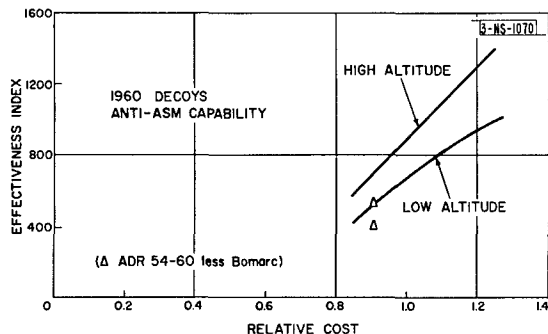


Fig. 15-2. Basic Lamp Light System.

Fig. 15-2. The Basic Lamp Light System, its scaled-up variation and its scaled-down variation, lies at 1.04, 1.20 and 0.88 on the relative cost scale.

The triangles located at 0.90 on the relative cost scale show the results of applying the same method of quantitative assessment to the ADR 54-60 system. To get a comparison on a common basis with the Lamp Light systems, the Bomarc missiles were

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removed from the ADR 54-60 plan before evaluation. At the same time, of course, the cost associated with this weapons system was also removed. These ADR 54-60 points fall below the trend curves for the Lamp Light contiguous systems. The relatively shallow contiguous cover of the ADR 54-60 system did not permit as large a fraction of the interception force to bear against a concentrated attack as did the Lamp Light system. Also, the allocation of Nike batteries to the target cities was better proportioned to their value on the scale being used for assessment (population) in the Lamp Light systems than in the ADR 54-60 plan.

It is worth emphasizing here that none of the Lamp Light systems is necessarily an optimum system of the kind under consideration at the cost level it represents - that is, the apportionment of funds among short-range missiles, medium-range interceptors, medium-long-range interceptors, and radar surveillance was made in each case on the basis of engineering judgment; the time scale of Project Lamp Light did not permit a serious attempt at optimization. This means, of course, that there may be similar systems that give a higher effectiveness index at the same relative cost.

It should be obvious that the numerous uncertainties in the input parameter values make it very unwise indeed to read off a single value of the effectiveness index from these curves, say 850, and think of it as meaning 850,  $\pm 5$  or  $\pm 10$ . Nevertheless, the rough size of the effectiveness index in the cost range considered is of interest and significance. It is significant, for example, that a bomber force in being, capable of launching 600 to 1200 bombers in a massed attack into the defense system, would be in the same general cost bracket as the defense systems.

Figure 15-3 shows the effect on the defense system effectiveness of negating the anti-air-to-surface missile capability assumed in the Basic Lamp Light System. The solid curves are a repetition of the curves of Fig. 15-2. The dashed curves are those obtained when it is assumed that the local surface-to-air missiles have no capability against the air-to-surface missiles of the enemy. This is approximately a 2-to-1 effect.

Figure 15-4 shows the effect of removal of the decoy threat. Again the curves of Fig. 15-2 are reproduced as solid curves (note the change of vertical scale). This is seen to be about a 2-to-1 effect in the defense's favor. The effectiveness indices in the range 2000 to 3000 must be regarded as very high indeed.

Finally, Fig. 15-5 shows the joint effect of removing the decoys and the anti-air-to-surface missile capability at the same time. As would be anticipated, the two effects tend to offset one another. However, there is a net improvement, indicating that the decoy effect is somewhat the stronger one.

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## Effectiveness vs Cost Results for Contiguous-plus-Remote Air Battle Systems

In order to assess the contribution of a remote air battle capability as discussed in Chap. 13, Sec. II to the over-all defense system effectiveness, remote air battle systems costing 0.03, 0.09 and 0.14 on the relative cost scale were added to the Basic Lamp Light System at 1.0 on the relative cost scale. The effectiveness vs cost relation for this combination of contiguous and remote air battle is shown by the solid bent curves of Fig. 15-6. The dashed curves in each case are the effectiveness-cost trends for the corresponding contiguous-only systems. The four cases presented include those in which the contiguous-only system was best and worst. In the intermediate cases, it is doubtful whether there is any significant difference in the effectiveness-cost trends indicated with or without the remote air battle system. In the uppermost case, where the contiguous system was relatively well off, the addition of the remote air battle

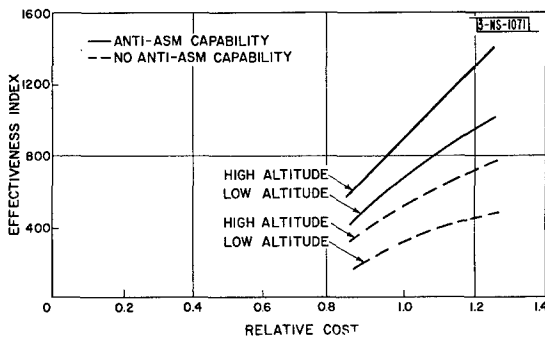


Fig. 15-3. Effect of loss of anti-ASM capability.

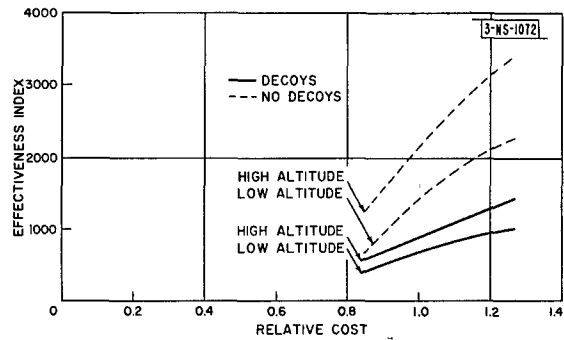


Fig. 15-4. Effect of removal of decoy threat.

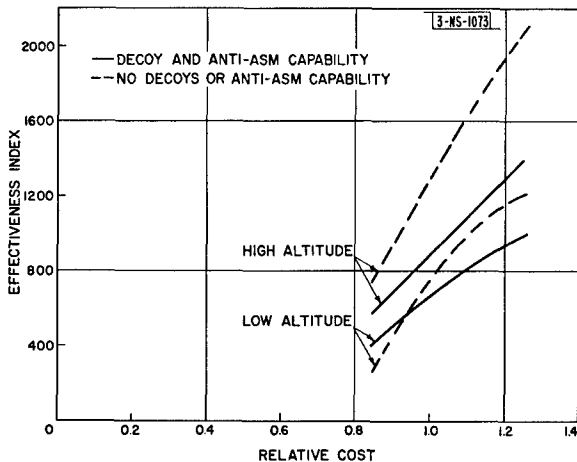


Fig. 15-5. Joint effect of no decoys and no anti-ASM.

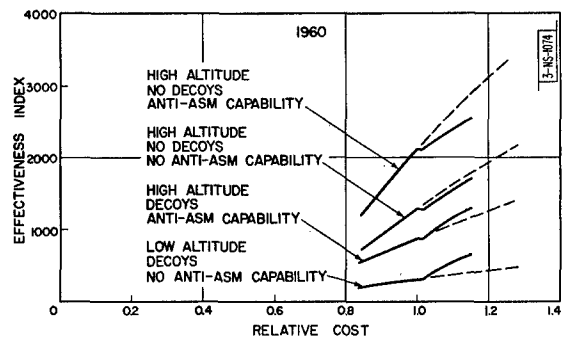


Fig. 15-6. Remote air battle system added at reference cost level.

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seems to be disadvantageous. On the other hand, in the bottom-most case, where the contiguous system was worst-off, a remote air battle system shows to advantage. As between the extreme cases, it might be argued that the gain of a few hundred points in the effectiveness index at a point where it is low initially is more important than the loss of a similar amount from an initial value that is very high. It is not surprising that the cases in which the remote air battle system shows to best advantage are those in which decoys are being used. The relative advantage of shooting down loaded decoy carriers is clear.

A conservative appraisal of the picture conveyed by Fig. 15-6 would seem to be that the remote air battle system has by no means been ruled out as being noncompetitive on the cold grounds of combat effectiveness. Under these circumstances, the numerous qualitative arguments advanced for and against such a system take on added importance.

Of the numerous nonquantitative arguments advanced against the remote air battle system, perhaps the weightiest are that (a) the rules of engagement for its effective combat use are particularly difficult to clarify, (b) such a system would be unduly provocative to our enemies, and (c) the various components needed to make the system work as described represent a relatively greater technical extrapolation of present developments than the components of the contiguous combat system. The latter point suggests that it might be more appropriate to add the remote air battle system as described in Chap. 13 onto a 1962 contiguous combat system for comparison rather than onto the 1960 one as was done.

Of the numerous qualitative advantages of such a system, the following seem worthy of re-emphasis:

The deterrent value of the system would seem to be relatively high because of the extent to which it complicates enemy planning. One aspect of this is the potential of this kind of system as a weapon of opportunity in the event, for example, of an intelligence break.

This system could be very useful in discouraging excessive spoofing.

The information obtainable from early contact with the enemy attacking force would be very useful in the contiguous air battle to follow.

These arguments suggest further study of the tactics to be employed in a remote air battle, and continuing efforts on technological developments that would make a remote air battle possible. Further, a study is required of what alterations in present cold-war rules of engagement are necessary before such a battle could be fought, and of

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the political feasibility of those alterations. Any problems that may exist here disappear, of course, during a state of war.

## The Perimeter Missile Variation of the Basic Lamp Light System

The alternative surface-to-air missile system considered by the Systems Group, involving a Talos belt around the heartland, was not given so thorough a quantitative evaluation as was the primary system. In the few cases (3) where a comparison was made, the primary system gave an effectiveness index roughly 25 per cent higher than that of the alternative system. The optimum enemy attacks for achieving 15 million deaths involved concentration on a relatively few peripheral targets - a circumstance particularly unfavorable to the perimeter scheme. Other measures of effectiveness than that used here might put the alternative system in a more favorable light.

It is felt that the qualitative factors that led to the consideration of this alternative system are of sufficient weight that it should not be finally ruled out of consideration without a more careful scrutiny.

## Typical Attack Traffic

The optimum attacks devised to determine the effectiveness index were designed under the assumption that the defense would not be SAGE-capacity limited. It is apparent that the raid densities and ECM activity presumed here imply that most of the air battle will, of necessity, be fought under relatively loose control conditions. The intention was to design the enemy attacks under the assumption that the SAGE System would not be a weak link, and then examine the resulting attack patterns to see, in retrospect, how much traffic would have to have been handled. The flow of traffic in a typical case is summarized in Table 15-II.

*Best estimate*

## Fall Out

As has been indicated, the optimum attacks used in determining the effectiveness index were designed under the assumption that the enemy would regard fall-out as a bonus, rather than a primary effect. The attacks designed on this basis can then be used to estimate the order of magnitude of the fall-out "bonus."

The time available for quantitative evaluation after the finalization of the Lamp Light systems did not permit any thorough exploitation of this opportunity. Rather cursory estimates in a few cases, however, seem to indicate that a likely order of magnitude for the fall-out bonus was about 20 per cent of the direct-effect damage, although it



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TABLE 15-II				
SAMPLE TRAFFIC SUMMARY*				
Battle Stage	Total Flying Objects	Bombs	Interceptors	SAM's
Approach	960	150	-	-
Entering far-contiguous battle	3380	150	540	-
Entering near-contiguous battle	2425	108	810	-
Leaving near-contiguous battle	1395	62	-	-
Entering local SAM battles	1455	62	-	5170
Bombs on target	-	9-10	-	-
*Optimum attack to achieve 15 million deaths against basic Lamp Light contiguous combat system (relative cost = 1.05); high-altitude attack, with decoys, with anti-ASM capability. Attack is off the Atlantic coast against New York City (A, B, and C), Philadelphia and Boston.				

might be more like 50 per cent in particularly unfavorable circumstances. No serious shelter program and 100 per cent detonation of shot-down bombs was assumed in these estimates.

There is some indication that fall-out effects should play a secondary role in the design of high-level defense systems. If the defense system is relatively strong, the optimal enemy attacks involve concentration of forces against a relatively few peripheral targets. The minimal attacks against the ADR 54-60 and Lamp Light systems that will cause 15 million deaths turned out to be against the five aiming points in New York City, Philadelphia, and Boston. Under these conditions, the distribution of shot-down bombs over the landscape is minimized. On the other hand, if the defense is weak enough that the enemy can afford to spread his force over a more dispersed set of aiming points, the enhancement of the fall-out effect may be of academic interest because almost

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everyone will be dead from direct effects of bombs on target. These considerations relate to air-breathing bomb carriers and, of course, are no longer valid in the case of the intercontinental ballistic missile.

## 1957 Effectiveness

Most of the quantitative evaluation effort was expended on the defense systems proposed for the 1960 time period. The necessity for an orderly, continuous build-up from the present defense system to the 1960 system was given full and adequate consideration by the Systems Group. The very limited build-up feasible by 1957, coupled with the very limited low-altitude capability technically achievable by then imply a low level of effectiveness. This foregone conclusion was verified by determining the effectiveness index of the 1957 variation of the Basic Lamp Light System in its posture against a relatively modest enemy capability.

The 1957 enemy attacks were designed using only TU-4 type aircraft, with no decoys, and a Mach 0.9 air-to-surface missile having a 30-mile range. The defense surface-to-air missiles were given no capability against low-altitude targets in this period.

The resulting values of effectiveness index (associated with about 0.3 on the relative cost scale) were: high-altitude, 220; low-altitude, 80.

The price of admission to the enemy in this time period would, of course, be even lower with a jet bomber capability.

## Some Aspects of Deterency

The 1960 defense systems considered by Project Lamp Light are formidable. The level of combat effectiveness implied by effectiveness indices of several hundred or a few thousand is certainly enough to give pause to any potential attacker. This is particularly so in view of the fact that these attacks are all-out, one-way missions in which a large force is expended to achieve an expectation of 9 or 10 bombs on target.

The "all or nothing" aspect of this situation enhances the deterrent value of such strong defenses even beyond their expected combat effectiveness. The enemy planner considering the irrevocable expenditure of such an attacking force is concerned not only with the expected or most likely outcome of the attack, but with all the possible outcomes. The uncertainties of estimating in advance the exact effectiveness of a defense system is a much more serious problem to the would-be attacker than to the defense planner. Just as the conservative defense planner will of necessity tend to underestimate the capabilities of his system, the conservative attack planner will tend to overestimate the defense capabilities. As a result, the enemy is unlikely, of his own initiative,

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to attack unless his force is appreciably stronger than the marginal value defining the effectiveness index.

The shape of the damage vs force characteristics exemplified in the curves of Fig. 15-1 is important in these considerations. It implies, for example, that an attacker with a marginally adequate force cannot hedge by holding a portion of the force in reserve for a second try, in the event that the first try is unsuccessful. Another interesting aspect is that a defense system that is marginally adequate, or less, against a well-planned and executed attack by the enemy's full force would offer an extremely high level of defense against a hastily launched attack in which only a one-half or three-quarters of the enemy's force could be brought to bear in a coordinated fashion.

## COSTS

Project Lamp Light has been mindful of the importance of good national economic management and hopeful that air defense might be greatly improved without intolerable increases in cost. Chapters 12, 13, and 14 contain cost estimates for systems and their components. While the systems we have studied imply some increased expenditures, we believe that some economies that partly balance them can be made. For example, we have suggested that, if an extended system of gathering early and continuous information regarding the enemy is available, a saving in operating personnel in our land-based and airborne radar-detection and intercept-control systems can be made. This saving can be made by operating with skeleton crews until the enemy has been detected by the extended system.

Costs are necessarily a function of the defense level we decide is necessary. The required level of defense has never been determined by any individual, organization or official agency.

We believe that we should have adequate defense to keep the chance of minor disasters reasonable and the chance of a major disaster (millions killed) very low.

Estimates of the cost of such a defense have been very high and estimates of the defensive value of an inexpensive defense system are low. Fortunately, the probability of an enemy's succeeding in making an attack that would be successful from his point of view is the product of the probability that he will try and the probability that he can do it if he tries. If both of these can be kept low or either one very low, the defense is adequate. A strong defense, which itself engenders a low probability of a successful attack, also creates a low probability of an attempt to break through it. The probability that the enemy will try is reduced again by our retaliatory threat and might be

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reduced by other methods. The Lamp Light study has been directed toward the creation of a stronger defense. We have sought a defense consistent with the foregoing argument rather than an impenetrable defense.

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**APPENDICES TO CHAPTER 15**

APPENDIX 15-A MAP-EXERCISE PROGRAM

APPENDIX 15-B MATHEMATICAL EVALUATION METHODS

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## APPENDIX 15-A MAP-EXERCISE PROGRAM

### INTRODUCTION

The evaluation of an air defense system cannot be absolute. Some elements of such a system are subject to mathematical analysis, but the whole must be judged in several ways, some of which are necessarily arbitrary. The best method of visualizing the system's effectiveness against an attack, and a good method of estimating its quality, is to take the position of an enemy and plan an operation against it, and then study the possible actions of the defense against the attack as it progresses step-by-step across a map.

Among items to be studied in this type of analysis are the following:

Variations in enemy tactics, such as raid size, aircraft attack altitude, use of ECM, submarine-launched missiles, etc.

Variations in enemy strategy, such as whether enemy targets are population, or SAC bases, or North American defenses.

Geographic influences, such as possible attack routes, the likelihood of involving forces outside North America, etc.

Rules of engagement (i.e., when to open fire, when to declare all-out war, etc.), and how they relate to quantity and quality of early information, actions over sovereign territory, response of SAC, etc.

Human factors as they affect decisions and their timing, evaluation of the deterrent value of defense and offense, psychological and physiological effects of nuclear weapons, etc.

Six hypothetical enemy attacks were planned in detail and were utilized, as time permitted, to examine defense-system responses. Both mass raids and small sneak raids were planned which were consistent with 1960 Soviet capabilities as best we could determine them. Brief descriptions of representative attacks are given in the following paragraphs.

### ATTACK PLANS

#### Attack Plans A1 and A2 Sneak Attack on SAC Bases

In this attack plan, the enemy long-range air army was scheduled to attack 24 U.S. Strategic Air Command bases with a small force of long-range jet bombers (Type 37). Each bomber was scheduled to arrive over its target at 2100 (CST) on 17 February 1960. Two bombers

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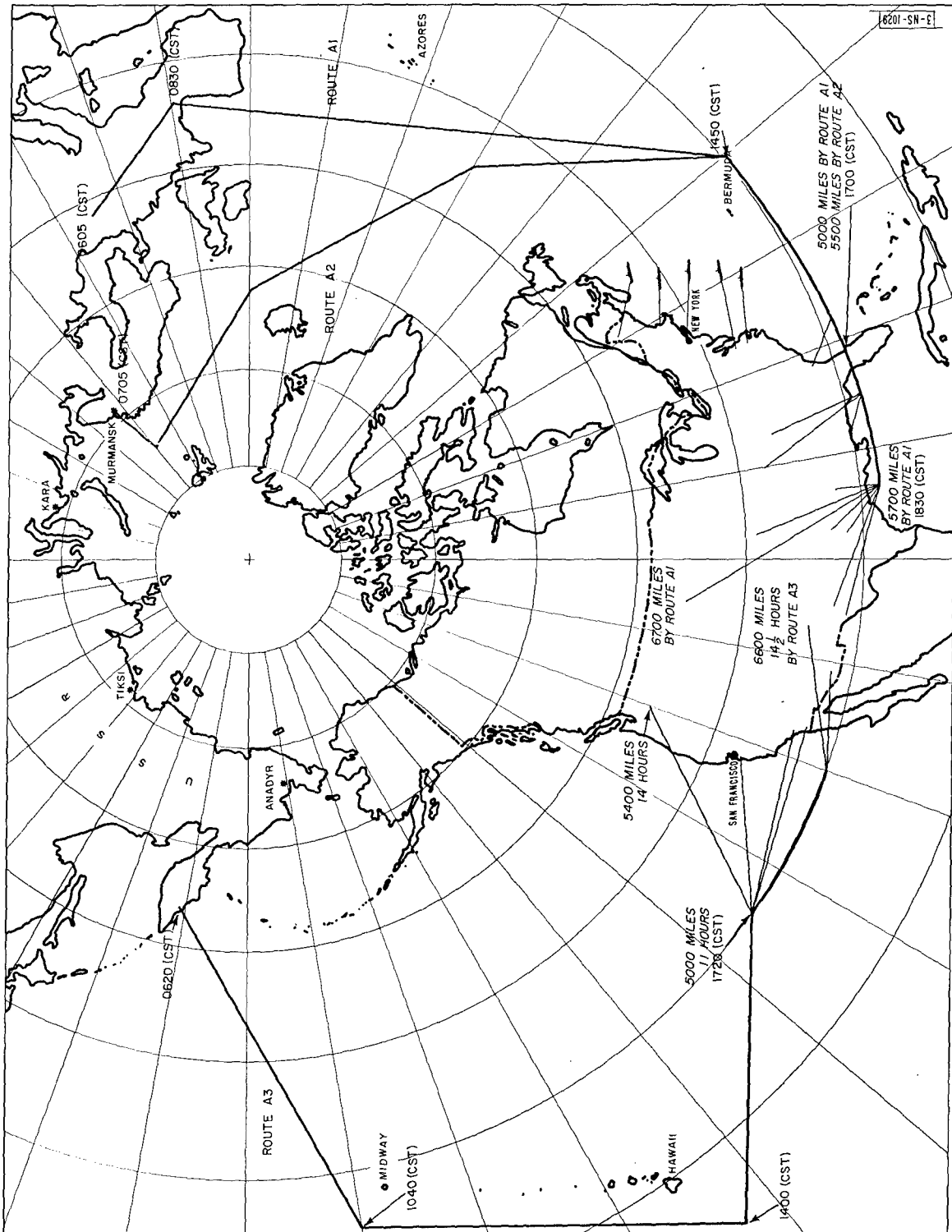


Fig. 15A-1. Attack Plans A1 and A2, sneak attack on SAC bases.

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were assigned to each SAC base assumed to be known to the enemy, and bomb delivery was to be by parachute from low altitude. An essential feature of the attack was the surprise element and, in order to safeguard it, all other aircraft movements were minimized until after the surprise raids had released their bombs. In particular, the follow-up mass air attack was to remain on the ground until after 2100 (CST) 17 February 1960. Aircraft were to fly along the paths labeled Route A1 in Fig. 15A-1 at 460 knots at high altitudes. The first pair of the 32 aircraft in the eastern surprise-attack force was assigned to Rapid City AFB in South Dakota, while the first pair of the 16 western attackers were assigned to strike Kirtland AFB in Albuquerque, New Mexico by Route A2. The times at which these lead aircraft reached various points along their routes are shown on Fig. 15A-1. Other aircraft in the eastern and western strike forces were scheduled to fly similar routes to those flown by the lead aircraft with only times and final approach routes changed in such a fashion that all aircraft would arrive over their respective targets at 2100 (CST) on 17 February 1960. When feasible, attack aircraft were to fly at low altitude (500 feet when flying contact and 1000 feet when on instruments) at 400 knots from the time they turned on to their final target heading.

This surprise air attack was to receive support from five submarines 200 miles off the eastern U. S. coast at 2100 (CST). Limestone AFB, Westover AFB, Boston, New York, Philadelphia, Washington, and Norfolk were to be hit by submarine-launched missiles. Enemy light bombers and fighters were to make a massive attack on air bases in Europe, North Africa and Alaska as soon as possible after 2100 (CST).

## Attack Plan B Sneak Attack on SAC Bases

A diffuse sneak raid was designed to deliver simultaneous blows to North American SAC bases at 2100 (CST) 17 February 1960. Flight paths for this raid are shown in Fig. 15A-2. Long-range jet bombers (Type 37) were assigned in pairs to each target. In order to minimize the probability of their detection, each pair was to descend to low altitude as soon as possible consistent with their maximum range capability for a one-way mission. A cruise speed of 400 knots true air speed was assumed throughout the mission. As in Plans A1 and A2, the mass follow-up force was scheduled to remain on the ground until after the surprise raid had completed its assignment.

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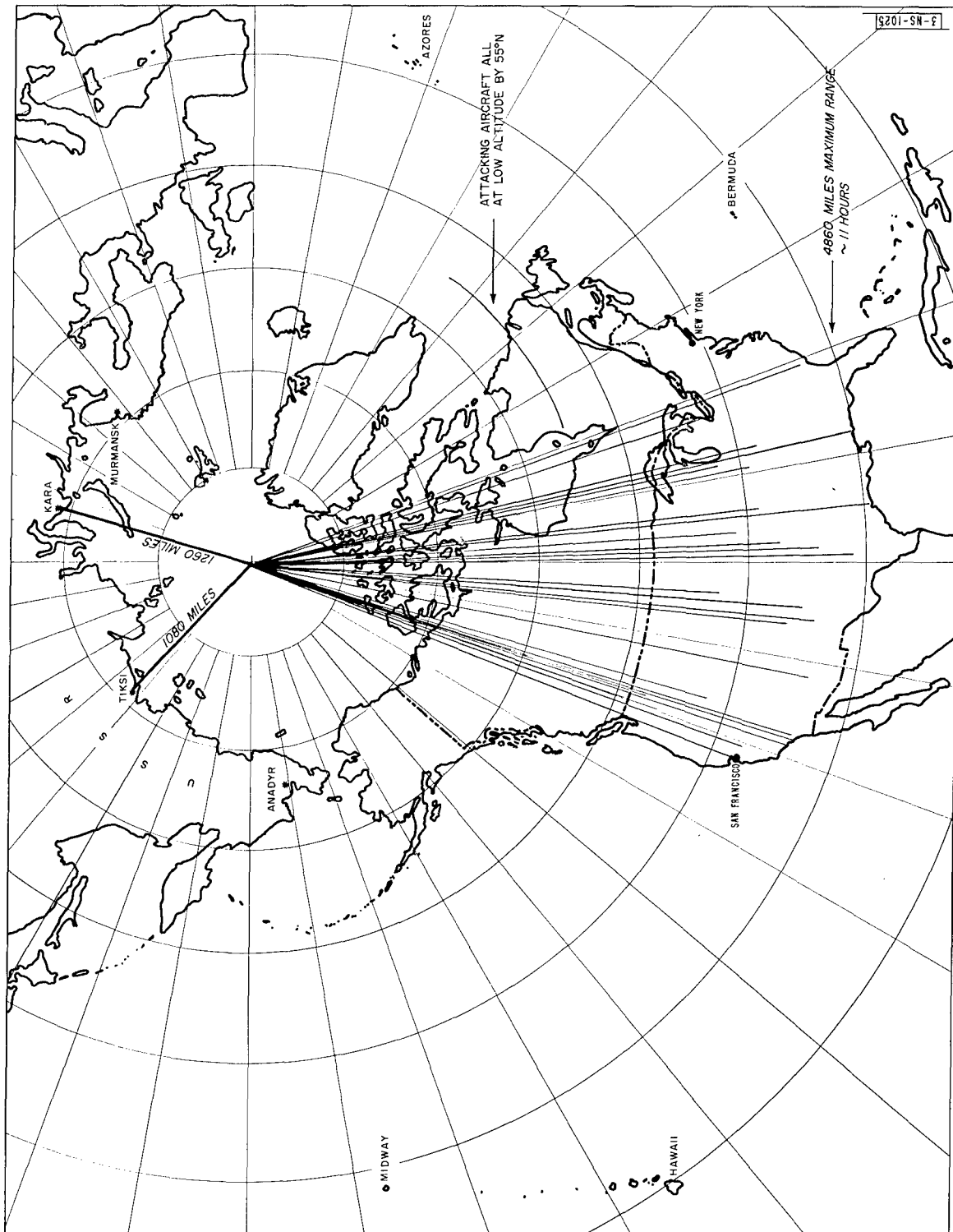


Fig. 15A-2. Attack Plan B, sneak attack on SAC bases.

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## Attack Plan C Concentrated Mass Attack on Heartland via Hudson Bay

A highly concentrated mass attack on the North American heartland, with a smaller simultaneous strike at western targets, was designed to follow the attack routes shown in Fig. 15A-3. Twenty-five enemy jet bombers were scheduled to leave Anadyr at 2100 (CST) on 17 February 1960 to strike population centers in western North America. At this same time, an initial wave of 70 jet bombers (Type 39) equipped with radar ferret equipment were to leave the Murmansk area. Their mission was to locate and destroy all radar stations along the 400-mile-wide approach route to the North American heartland shown in Fig. 15A-3. Each aircraft was allotted 10 low-yield, air-to-surface or air-to-air, rocket-propelled atomic bombs. The initial wave of radar killers was followed half an hour later by 900 jet bombers (Type 39) in a box pattern 50 miles wide, 240 miles deep, and three layers high. All second-wave bombers carried ECM and were to emit a maximum radar jamming signal as soon as defense weapons were encountered.

Five hundred of the second-wave aircraft were loaded with hydrogen bombs and the remainder with decoys. Their targets included 40 aiming points in central and eastern United States and Canada extending from Montreal to Norfolk and from Boston to Minneapolis. Where possible, low-altitude penetrations of local defenses were to be made. The last of the aircraft to reach target were those assigned to Norfolk, and these were scheduled to strike at 0640 on 18 February 1960.

## Attack Plan D Concentrated Mass Attack on Heartland via the Atlantic

This plan is identical in concept to Attack Plan C with the exception of the attack route for the heartland strike. The mass strike was scheduled to approach the North American continent from over the Atlantic after defense system radars had been knocked out by a small force of radar killers as in Plan C. The attack routes for this raid are shown in Fig. 15A-4.

## Attack Plan E Multipath Mass Raid on Heartland

A multipath mass raid was designed to produce a maximum deleterious effect on the North American defenses by enemy use of active jamming. Attack routes for the various raid elements are shown in Fig. 15A-5 together with the number of aircraft flying each route. A total of 980 medium-range jet bombers (Type 39) and 150 short-range bombers (IL-28) was used in the attack. All elements of the raid were

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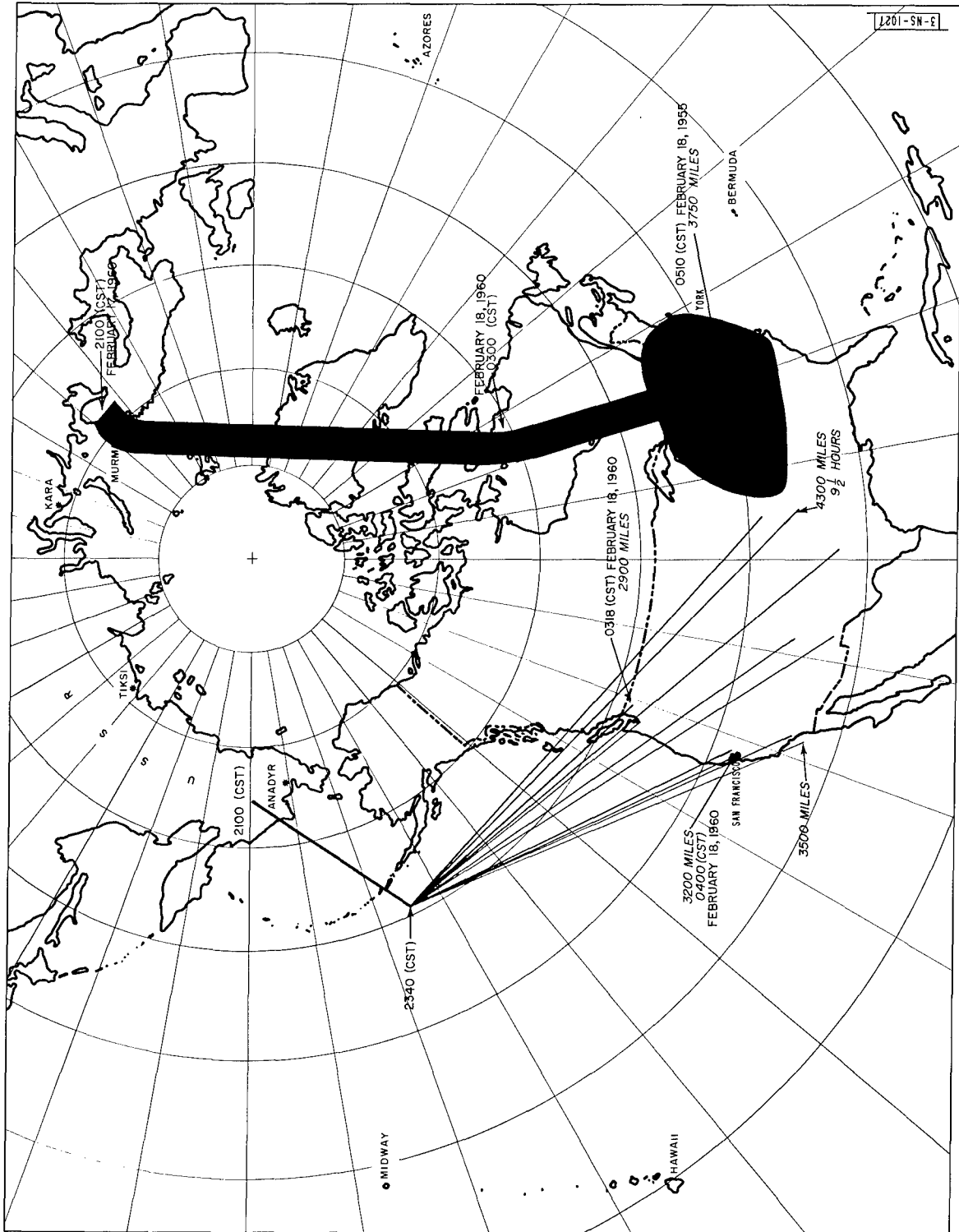


Fig. 15A-3. Attack Plan C, mass attack on the heartland via Hudson Bay.

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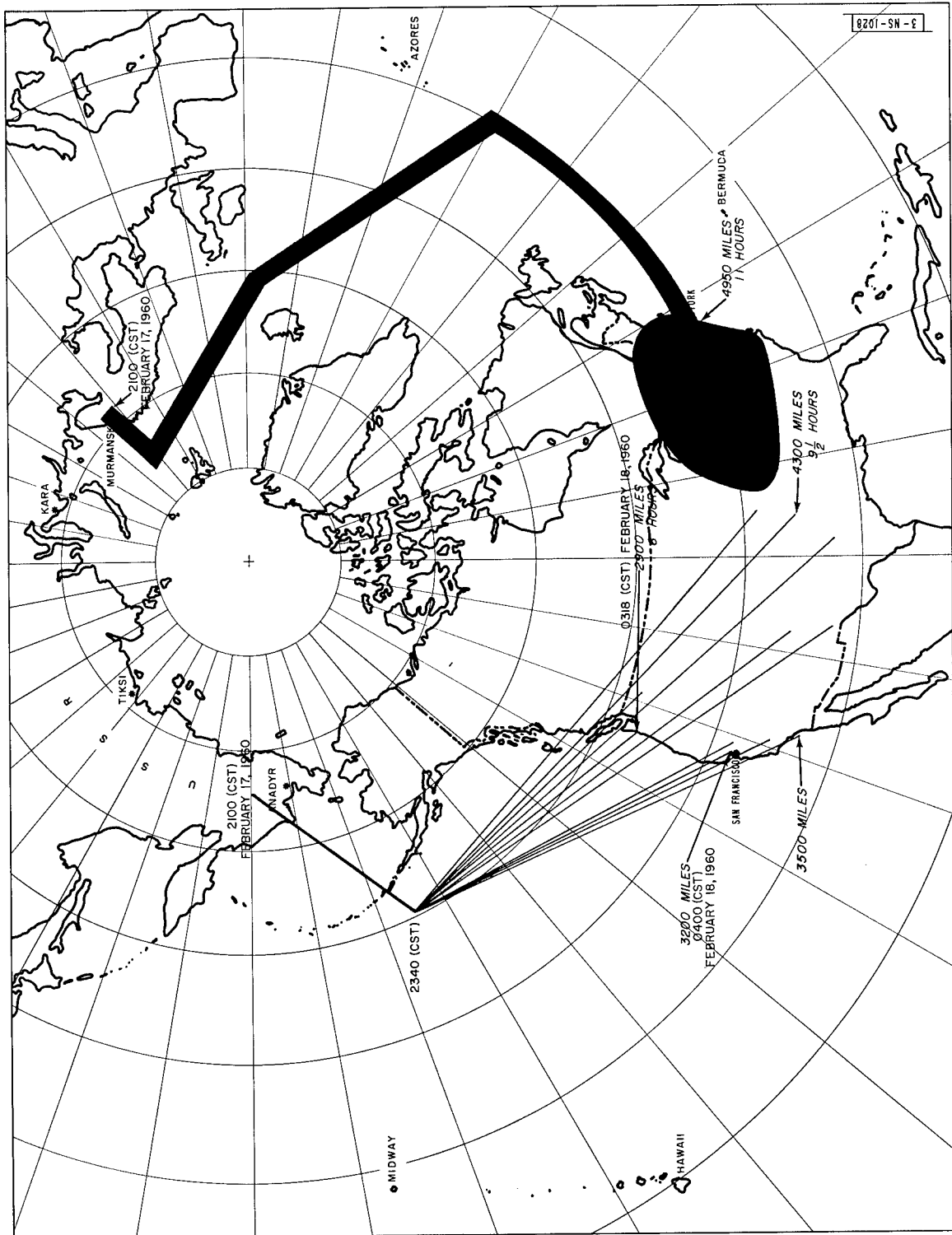


Fig. 15A-4. Attack Plan D, mass attack on the heartland via Atlantic.

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coordinated so as to be detected almost simultaneously by the North American warning lines. Each aircraft was to make most efficient use of its 2000 pounds of ECM equipment to produce poor raid-size assessment and, therefore, poor defense weapons assignment and decreased defense weapons efficiency. As a particular example, the 18 aircraft from Tiksi directed to the Pacific northwest were spaced to simulate the large 106-aircraft raid on the Pacific northwest from Anadyr when the active jamming equipment was turned on. Similarly, the heartland and east coast formations were spaced to look alike with their active jamming equipment turned on. As the echelons were brought under attack by North American defense weapons, each aircraft was scheduled to cycle its jamming equipment off and on at random in order to decrease the efficiency of the already-lower-than-expected number of weapons brought to bear by the North American defenses. Formations were generally composed of 10-aircraft echelons spaced at 15-mile intervals along the flight path and 50 miles apart across the flight path. Within each echelon, a 2-mile minimum aircraft spacing was maintained.

REMARKS  
ON  
ATTACK PLANS

### Sneak Attack of Plan A1

All participants agreed that flying over Europe to attack North America is a very poor enemy tactic.

There was a high probability that all enemy bombers would have been shot down over Europe, but even if none were destroyed the surprise element would, with almost complete certainty, have been lost. It appears obvious that, once detected, a raid of small numbers of aircraft could be easily destroyed by any of the 1960 defense systems that were considered. In the case of Plan A1, detection of the Krakow-based raiders seemed almost certain in at least three independent zones: (1) over Europe; (2) upon entrance of contiguous radar zone off eastern U. S.; (3) upon the high-altitude crossing of Florida.

Even if these detections were not made, there would still be low-flying aircraft over the United States for  $2\frac{1}{2}$  hours prior to the scheduled bomb release time of 2100, and these aircraft would offer further opportunity for SAC to be alerted.

Early detection of the surprise raid of Plan A1 afforded a great opportunity of striking a crippling blow to the enemy's air strength that was forced to remain on the ground in order to enhance the probability of success for the surprise raid. Wide-awake and well-armed air forces of NATO, Far East Air Command, Alaskan Air Command and others located geographically near the enemy could have greatly reduced, if not prevented, any massive follow-up strike planned by the enemy. Rules of engagement for

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our own forces, as well as for the overseas forces mentioned above, were very critical factors in determining the outcome of this map exercise. Much variation was observed in the time at which different groups made fundamental decisions. Questions such as the following were not answered with unanimity: (a) When are we in war? (b) When can we start shooting (particularly with weapons capable of combat far from the North American Continent)? (c) Whether and when shall SAC forces be instructed to depart on their retaliatory mission?

## Sneak Attack of Plan A2

The sneak attack of Plan A2 was characterized by the same general events as in Plan A1 except that violation of sovereign territory did not take place so early along the attack route. This produced even more variation than in Plan A1 in the time at which fundamental decisions were made, as well as more difficulty in reaching decisions.

## Sneak Attack of Plan B

The sneak attack of Plan B was a failure for the enemy because his aircraft were forced to fly at high altitude at least until they passed the 60<sup>th</sup> parallel. This allowed almost certain detection before enemy aircraft reached the point from which they could descend to complete their missions at low altitude. This attack was followed by the same mass attack that followed the sneak attacks of Plans A1 and A2. Decisions were made easier and faster in this case because of the violation of sovereign Canadian territory but the results of the mass attack were the same as in Plans A1 and A2.

## Mass Attacks of Plans C, D and E

The initial wave of radar killers appeared to be a very potent and practical means for reducing the effectiveness of North American defenses. In the attack of Plan C, for instance, the radar killers were able to deny any raid-size assessment by the defenses until after the main enemy force had penetrated to about the 50<sup>th</sup> parallel - only one hour before the raid would enter the heartland.

The mass attacks of Plans C and D were easily detected and identified. The battle that ensued, after contact was made by North American defense weapons, was so highly concentrated and confused that the enigma was not amenable to further study on the map. Concentrated battles of this type were analyzed mathematically as described in Appendix 15-B.

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With respect to the response of the ADR 54-60 system against such mass attacks, it was specifically noted that, when the medium-range, medium-long-range, and long-range interceptors were put on alert status only when the DEW line was penetrated and were subsequently not scrambled until the enemy entered the contiguous radar cover, all interceptions took place within MRI radius. There appeared to be very few cases where the ADR 54-60 contiguous radar cover would permit maximum use of the radius capabilities of the medium-long and long-range interceptors described in ADR 54-60.

It appears that, for approximately equal cruise speeds for bomber and interceptor, the contiguous data-zone depth should be essentially twice the interceptor radius.

The mass attack of Plan E disclosed the fact that there was an almost complete lack of understanding as to the degree of efficiency with which the defense system could operate in the presence of active jamming. As a result, map exercises involving this specific raid were not completed. However, most participants were convinced that if we could negate the effect of enemy ECM the raid would produce a less confused situation for the defenses than attacks of Plans C or D and, therefore, a higher defense efficiency would be expected.

## GENERAL SUMMARY OF MAP-EXERCISE PROGRAM

Both the map exercises and the discussions that they stimulated engendered several significant observations. It is to be appreciated that these have been extracted from a limited number of map exercises; none the less, they appear to be worthy of consideration in the design of defense systems. No attempt has been made to give a comprehensive listing of desirable defense-system features but only to give those important features that received emphasis from the map-exercise program. The most significant map-exercise observations, along with brief explanatory remarks, are summarized below.

Enemy use of electronic countermeasures, to keep us from gathering and/or communicating information, can be disastrous and is to be expected unless we can turn such a tactic to the enemy's disadvantage.

Enemy attacks on radar stations located outside defended areas appear to be worthy of the efforts required. The use by the defense of decoy radar stations could greatly increase the enemy effort required to ensure the success of such attacks.

A sound and strong program to decrease the vulnerability of SAC by increased dispersal and faster response, in



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combination with either of the 1960 defense systems considered at Lamp Light, would appear to give adequate protection to SAC bases against any of the threats that were considered. Surprise attacks on SAC bases in 1960 appeared to be very poor risks for the enemy because of the very solid and extensive information zones that we should have by that time. Surprise attacks may also force the enemy to leave his mass force in vulnerable positions on home bases until after the surprise raid is known to North American defenses.

Essential factors in determining the outcome of any enemy attack on the North American continent are rules of engagement relating to: (1) When does the war begin? (2) When can we shoot? (3) When will our allies act? (4) When will SAC be dispatched? etc.

Any defense system must provide adequate time for responsible commanders to make the decision that an attack is under way, to plan operations, to inform all interested parties and to commit weapons in an optimum fashion.

One-way missions make low-altitude jet bomber penetrations of our defenses a possibility. Thus, we must prepare to cope with such attacks either by achieving an effective low-altitude weapons system or by attacking the enemy far from the North American target area while his jet bombers are still forced to fly at high altitude in order to complete their missions.

All who participated in the map-exercise program were impressed with the difficulty of planning an attack on the North American continent. Known defense-system obstacles were observed to have a very strong influence on the attack plans formulated. Indeed, many attack plans were rejected by the enemy delegates after consideration of the probable obstacles in the way. Since the enemy must be credited with some knowledge of the true obstacles, the advantages that could accrue to our defenses from disclosure of judiciously distorted facts, features, or capabilities of our defense appear worthy of further study.

Much time was devoted to discussions of the desirability of a remote air battle. It was agreed that its qualitative features such as the long period of harassment and attempted destruction, and the less-restricted use of nuclear weapons, could be very potent assets to our defense even if its kill potential were very small.

*T. B. Cook*

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## APPENDIX 15-B MATHEMATICAL EVALUATION METHODS

### INTRODUCTION

The central principles around which the mathematical framework for evaluating the Lamp Light defense systems was developed are summarized by: evaluation, over-all effectiveness and optimized attack.

The Evaluation Group was obligated to assess defense systems as designed and specified by the Systems Groups. This required the evolution of evaluation techniques not dependent on freedom to rearrange the system being assessed.

The defense systems submitted for evaluation involved a complex of interacting weapons systems. The objective of the evaluation procedures was to assess the over-all effectiveness of each defense system. Hence it was necessary to take into account, in so far as they are understood, the interactions between the different air battle stages.

The selection of the specific detailed attack variation against which each defense system was gauged was based systematically on the choice of the best alternatives from the enemy's point of view.

### ASSIGNMENT EFFICIENCY FUNCTIONS

It is customary to describe the effectiveness of individual defense weapons in terms of a unit probability of kill. In the case of an interceptor, for example, this number reflects estimates of the probability of no abort or gross vectoring error, the probability of detection of a target and conversion to an armament pass, the probability of a kill on the first armament pass, the probability of reacquisition for another pass, and so on.

This unit probability of kill or kill potential per interceptor sortied is precisely the expected number of kills (in the mathematical sense) in a battle involving only one interceptor. In a battle involving many interceptors, the expected number of kills will, in general, be less than the total kill potential (i.e., the number of interceptors times the kill potential per interceptor) thrown into the battle. This is due to the imperfect distribution of interceptors over surviving targets in a confused battle situation. In general, the conversion of kill potential into actual kills will be the more efficient: the smaller the ratio of kill potential to initial raid size, the larger the ratio of the battle length to a characteristic over-all kill assessment, reassignment, and reattack time of the system, and the tighter the over-all defense control (in the

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sense of being able to bring interceptor No. 373 to bear against bomber No. 694 if desired).

When the initial raid size is large, as in the cases of present interest, the expected fraction of attackers surviving the battle can be regarded as a function  $\phi(\tau)$ , where  $\tau$  is defined as

$$\tau = \frac{\text{defense kill potential}}{\text{initial raid size}}$$

This function depends on the battle conditions mentioned above.

In the confused battle situation resulting from high spatial densities of attackers and interceptors, coupled with high-level ECM and CCM activity, relatively loose control is inevitable. It is therefore instructive to visualize an idealized battle situation in which a wave of interceptors is directed into a swarm of attackers, each interceptor simultaneously making an independent random choice of a target for attack. The assignment efficiency function for this extreme case is the exponential curve 1 in Fig. 15B-1. The opposite extreme - perfect efficiency - is represented by the straight

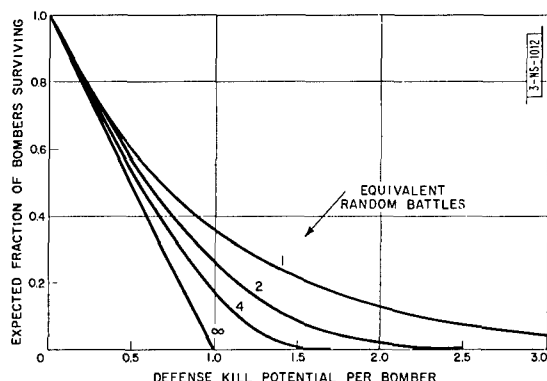


Fig. 15B-1. Assignment efficiency functions.

a number of equal successive waves, the kills of one wave being recognized and taken into account in the assignment of the next wave. This is the basis for curves 2 and 4 of Fig. 15B-1 as well as for curves 3 and 5 - approaching the straight line as the number of sub-battles increases.

This n-battle random set of efficiency functions was used in a semi-empirical fashion to degrade the various defensive weapons systems in the evaluation. The local defense surface-to-air missiles were given a 2-battle random assignment efficiency. The near-contiguous interceptor battle (MRI's and MLRI's) was also given a 2-battle random

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efficiency. The far-contiguous interceptor battle was given one battle random for each 20 minutes of combat (experienced by a given attacker) after the first 10.

It should be noticed (Fig. 15B-1) that the differences between the various efficiency functions become insignificant in a battle in which only a modest fraction of the attacking force is killed. Small "bites" are almost perfectly efficient in any case. Hence, the relative efficiency of successive over simultaneous engagement, especially in loose-control situations.

The n-battle random family of assignment efficiency functions can be computed from the following:

$$\begin{aligned} \phi_1(\tau) &= e^{-\tau} \\ &\vdots \\ \phi_n(\tau) &= \phi_{n-1} \left( \frac{n-1}{n} \tau \exp[1/n \tau] \right) \cdot \exp[-(1/n) \tau] \end{aligned}$$

In the following sections, subscripts as above will indicate when one of these particular efficiency functions is being discussed. When no subscript is appended to a  $\phi(\tau)$ , the treatment in which it appears is intended to be valid for any appropriate choice of  $\phi(\tau)$ .

## CASCADED EXPECTATIONS AND THE POISSON DAMAGE ESTIMATE

In spite of the well-recognized significance of variabilities in defense system performance, it was necessary to work almost entirely with expected values because of the Project Lamp Light time scale. It was

further necessary to repeatedly approximate the expected output of a cascade of stages by taking the expected output of the first as the input to the second, and so on.

At one stage of the battle analysis, however, it is essential that the statistical distribution of outcomes be considered in more detail. This is in estimating the expected damage at a given aiming point. The assignment of values to aiming points has been made on the basis that one bomb on target at an aiming point does damage equal to the value of the aiming point. Hence the relationship among damage, value, and bombs on target at the  $i^{\text{th}}$  aiming point is:

$$\begin{aligned} d_i &= v_i \text{ if } n_i = 1, 2, 3, \dots \\ &= 0 \text{ if } n_i = 0 \end{aligned}$$

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The significant statistic of the integer-valued random variable  $n_i$  is then the probability that  $n_i$  is one or greater. If only the expected value  $s_i$  of  $n_i$  is given, it is not possible in general to determine the probability that  $n_i > 0$ . Fortunately, the circumstances of present interest constitute an exceptional case.

The defense system assessments to be made involve high-level defenses, in the sense that the probability of any individual bomb entering the system surviving to become a bomb on target is small. This characteristic is, indeed, guaranteed when the minimum enemy force to achieve a specified damage level is the focus of interest. In spite of the low individual probability of bomb survival, however, the optimal enemy attacks will involve a sufficient concentration on those aiming points chosen for attack that the expected number of bombs on target at each such point will be of order unity (more like 1 than like 0.1 or 10). This combination of low individual probability of an event with a moderate expected number of occurrences – at the end of a complex sequence of independent random processes – is a familiar one in physical situations. The distribution of outcomes in such situations is well approximated by the familiar Poisson distribution function:

$$\text{prob}(n_i = x) = \exp[-s_i] \frac{s_i^x}{x!} \quad x = 0, 1, 2, \dots$$

where  $s_i$  is the expected value of  $n_i$ , that is

$$s_i \equiv \sum_{x=0}^{\infty} x \cdot \text{prob}(n_i = x)$$

For this distribution, the

$$\begin{aligned} \text{prob}(n_i > 0) &= 1 - \text{prob}(n_i = 0) \\ &= 1 - e^{-s_i} \end{aligned}$$

Hence, the expected value of the damage at the  $i^{\text{th}}$  aiming point is given in terms of the expected number of bombs on target at the  $i^{\text{th}}$  aiming point by the Poisson Damage Estimate:

$$d_i = v_i (1 - e^{-s_i}) \quad (1)$$

This relation permits working with expected numbers of surviving bombs throughout the analysis while facing up to the fact that there can only be an integral number of bombs on a given target and that the value is destroyed by the first one.

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## A PURE AREA DEFENSE MODEL

Consider a target area containing a number of aiming points and defended solely by interceptors with radii of action larger than the target area. Suppose that a raid approaches this area and splits into sub-raids directed at some set of aiming points. Suppose further that all raiders carry bombs. We now inquire how the defense commander should allocate his forces over the sub-raids - assuming that all sub-raids are to be engaged.

Let

$v_i$  = value of  $i^{\text{th}}$  aiming point (arranged so that  $v_{i+1} \leq v_i$ ),

$b_i$  = bombs in  $i^{\text{th}}$  sub-raid,

$b$  = total bombs in raid,

$h_i$  = defense kill potential allocated to  $i^{\text{th}}$  sub-raid,

$h$  = total defense kill potential,

$d_i$  = expected damage at the  $i^{\text{th}}$  aiming point,

$d$  = total expected damage.

$\tau_i = h_i/b_i$ ,

$\tau = h/b$ ,

$\phi(\tau_i)$  = expectation of survival of a bomb in the  $i^{\text{th}}$  sub-raid,

$N$  = number of aiming points attacked,

From Eq. (1),

$$d_i = v_i \left\{ 1 - \exp[-b_i \phi(\tau_i)] \right\} \quad (2)$$

The defense commander's problem is to minimize

$$d = \sum_{i=1}^N d_i \quad (3)$$

for the set of  $v_i$ 's and  $d_i$ 's chosen by the attacker, subject to the limitation of the fixed total defense kill potential available

$$h = \sum_{i=1}^N h_i \quad (4)$$

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The condition for this is that

$$\frac{\partial}{\partial h_i} (d + \mu h) = 0 \quad , \quad (5)$$

where  $\mu$  is a parameter independent of  $i$ . Substitution of (3) and (4) into (5) yields the "marginal utility" condition

$$\frac{\partial d_i}{\partial h_i} = -\mu \quad . \quad (6)$$

Substitution in (2) gives

$$v_i \exp[-b_i \phi(\tau_i)] \cdot \phi'(\tau_i) = -\mu \quad . \quad (7)$$

In principal, this equation determines  $h_i$  as a function of  $\mu$ ;  $\mu$  can then be determined by the condition

$$\sum_{i=1}^N h_i = h \quad .$$

We now turn to the other side of the game and inquire how the enemy commander, knowing the defense commander's allocation doctrine, should have allocated his bombs over the aiming points chosen for attack in order to do the most damage for a given total number of bombs. His problem is to maximize

$$d = \sum_{i=1}^N d_i$$

subject to a given value of

$$b = \sum_{i=1}^N b_i \quad .$$

This leads to the condition

$$\frac{\partial d_i}{\partial b_i} = \lambda \quad .$$

Substitution in (2) gives

$$v_i \exp[-b_i \phi(\tau_i)] \cdot [\phi(\tau_i) - \tau_i \phi'(\tau_i)] = \lambda \quad . \quad (8)$$

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Division of (8) by (7) discloses the necessary condition

$$\tau_i - \frac{\phi(\tau_i)}{\phi'(\tau_i)} = \lambda/\mu \quad . \quad (9)$$

Now the function of  $\tau_i$  constituting the left side of this equation is not identically constant unless  $\phi(\tau_i)$  is exactly a linear function of  $\tau_i$  - an unrealistic exceptional case. In all other cases, (9) implies that  $\tau_i$  is independent of  $i$ , that is, that

$$\tau_i = \tau \quad , \quad \text{a constant} \quad . \quad (10)$$

This interesting result says that, against the optimal enemy attack, the defense commander's best allocation is a uniform kill potential per bomber over the various sub-raids. It can further be verified that, if the defense commander adopted uniform allocation as a general rule, the enemy could do no better than to play along by sending in the sub-raid division for which this doctrine is optimal. The uniform allocation result also clarifies, in retrospect, questions as to how soon the defense commander can tell the destination of a sub-raid, the effect of multiple branching raids, and so on. The uniform allocation doctrine does not require clairvoyance for its application.

Substituting (10) into (7), solving for  $b_i$ , and evaluating  $\mu$  from

$$\sum_{i=1}^N b_i = b \quad ,$$

establishes the final results:

$$\frac{b_i}{b} = \frac{h_i}{h} = \frac{1}{N} + \frac{1}{s} \ln \frac{v_i}{\tilde{v}} \quad , \quad (11)$$

$$d_i = v_i - \tilde{v} e^{-s/N} \quad , \quad (12)$$

$$d = N(\bar{v} - \tilde{v} e^{-s/N}) \quad , \quad (13)$$

where

$s = b \phi\left(\frac{h}{b}\right)$  is the total expected number of bombs on target,

$\bar{v} = \frac{1}{N} \sum_{i=1}^N v_i$  is the arithmetic mean value of the aiming points attacked, and

$\tilde{v} = \left(\prod_{i=1}^N v_i\right)^{1/N}$  is the geometric mean value of the aiming points attacked.



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We now turn to the question of which aiming points the enemy should choose to attack. Equation (12) shows that the amount of value protected (i.e.,  $v_i - d_i$ ) at each aiming point attacked is the same. Thus the damage contribution of a more valuable target is more than that of a less valuable. This implies an enemy target selection by going down a list of targets ordered in descending value to some cut-off point. For a given target list the number of targets,  $N$ , to be included can be determined for a fixed value of  $s$  by trying  $N = 1, 2, 3$ , etc., and choosing the value giving the largest  $d$  while satisfying  $b_i > 0$  for  $1 \leq i \leq N$ .

This procedure determines, for a given target system,  $N$ ,  $b_i/b$ ,  $h_i/h$ ,  $d_i$  and  $d$  as functions of  $s$  (the expected total number of bombs on target) alone. Recall that  $s$  is given in terms of total forces by

$$s = b \phi\left(\frac{h}{b}\right) \quad , \quad (14)$$

so that  $b$  can be determined for given  $d$  or vice versa when  $h$  is specified.

If a uniform dilution of the raid with decoys is introduced, the results in terms of  $s$  are unchanged; only the argument of  $\phi$  in (14) is changed by a constant factor. If a fixed number of decoys is allowed as a substitute for a bomb, the modified form of (14) can be used to determine the decoying ratio so as to give the desired  $s$  (established by the desired  $d$ ) at a minimum total cost in bombers plus decoy carriers - or to determine the maximum damage achievable as a function of total enemy force. The exemplary curves of Fig. 15-1 were obtained by this method, using the target values of the heartland and three different interceptor forces.

## LOCAL-PLUS- INTERCEPTOR DEFENSE MODEL WITH TWO-STAGE DECOYING

Consider a raid penetrating an interceptor battle zone, then breaking into sub-raids to attack a given set of aiming points defended by local SAM (surface-to-air missile) defenses. Each enemy carrier entering the interceptor battle carries either a bomb in an air-to-surface missile, 3 long-range decoys, or 9 short-range decoys. The long-range decoys are launched at the beginning of the interceptor battle and surviving ones continue in through the SAM battles to the different aiming points. The surviving short-range decoy carriers launch their decoys at the beginning of the SAM battle, and the surviving bomb carriers launch their ASM's there. All carriers continue on after launching to further dilute the defenses.

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Let

$v_i$  = value of  $i^{\text{th}}$  aiming point,

$b_i$  = number of bomb carriers briefed for  $i^{\text{th}}$  aiming point,

$x_i$  = number of long-range decoy carriers briefed for  $i^{\text{th}}$  aiming point,

$y_i$  = number of short-range decoy carriers briefed for  $i^{\text{th}}$  aiming point,

$m_i$  = SAM kill potential (vs ASM's) at the  $i^{\text{th}}$  aiming point,

$$b = \Sigma b_i,$$

$$x = \Sigma x_i,$$

$$y = \Sigma y_i,$$

$f$  = number of flying objects entering interceptor battle,

$$= b + 4x + y,$$

$\phi(f)$  = expectation of survival in interceptor battle,

$c$  = total initial enemy force =  $b + x + y$ ,

$$\tilde{b}_i = b_i \phi,$$

$$\tilde{x}_i = x_i \phi,$$

$$\tilde{y}_i = y_i \phi,$$

$$\tilde{b} = b\phi,$$

$$\tilde{x} = x \phi,$$

$$\tilde{y} = y \phi,$$

$$\tilde{f} = f\phi = \tilde{b} + 4\tilde{x} + \tilde{y},$$

$$\tilde{\tau}_i = \frac{m_i}{2\tilde{b}_i + 4\tilde{x}_i + 10\tilde{y}_i} .$$

$\tilde{\phi}(\tilde{\tau}_i)$  = expectation of survival of an ASM at the  $i^{\text{th}}$  aiming point.

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The expected damage at the  $i^{\text{th}}$  aiming point is

$$d_i = v_i \left\{ 1 - \exp[-\tilde{b}_i \tilde{\phi}(\tilde{\tau}_i)] \right\} \quad (15)$$

The enemy's problem is to choose the  $b_i$ 's,  $x_i$ 's and  $y_i$ 's so as to achieve a given total expected damage

$$d = \Sigma d_i$$

for the smallest possible total initial force,  $c$ . Now, in so far as the interceptor battle is concerned, it is immaterial to the enemy whether the loaded carriers that he has to deliver through it are bomb carriers or short-range decoy carriers. There is then a sub-optimization problem of maximizing  $d$  for given  $\tilde{b} + \tilde{y}$  or, equivalently, minimizing  $\tilde{b} + \tilde{y}$  for given  $d$ . This leads to the marginal utility relations

$$\frac{\partial d_i}{\partial \tilde{b}_i} = 5/4\lambda \quad , \quad (16)$$

and

$$\frac{\partial d_i}{\partial \tilde{y}_i} = 5/4\lambda \quad . \quad (17)$$

Substituting (15) into these relations gives

$$v_i \exp[-\tilde{b}_i \tilde{\phi}(\tilde{\tau}_i)] \cdot [\tilde{\phi}(\tilde{\tau}_i) - 2 \frac{\tilde{b}_i}{m_i} \tilde{\tau}_i^2 \tilde{\phi}'(\tilde{\tau}_i)] = 5/4\lambda \quad (18)$$

and

$$v_i \exp[-\tilde{b}_i \tilde{\phi}(\tilde{\tau}_i)] \cdot [-10 \frac{\tilde{b}_i}{m_i} \tilde{\tau}_i^2 \tilde{\phi}'(\tilde{\tau}_i)] = 5/4\lambda \quad . \quad (19)$$

Manipulation of these two relations and combination with (15) yields

$$\frac{\tilde{b}_i}{m_i} = f(\tilde{\tau}_i) \quad , \quad (20)$$

and

$$\frac{\lambda}{v_i} = \tilde{\phi}(\tilde{\tau}_i) \exp[-m_i g(\tilde{\tau}_i)] \quad (21)$$

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and

$$\frac{d_i}{v_i} = 1 - \exp [-m_i g(\tilde{\tau}_i)] \quad , \quad (22)$$

where

$$f(\tilde{\tau}_i) \equiv -\frac{1}{8} \frac{\tilde{\phi}(\tilde{\tau}_i)}{\tilde{\tau}_i^2 \tilde{\phi}'(\tilde{\tau}_i)}$$

and

$$g(\tilde{\tau}_i) \equiv \tilde{\phi}(\tilde{\tau}_i) \cdot f(\tilde{\tau}_i) \quad .$$

For a specific choice of the function  $\tilde{\phi}$  and given values of  $v_i$ 's and  $m_i$ 's, use of (20) to (22) permits the computation of  $d_i$  vs  $\tilde{\tau}_i$  and  $\lambda$  vs  $\tilde{\tau}_i$  curves, and hence of  $d_i$  vs  $\lambda$  curves for each value of  $i$ . Summing the  $d_i$  vs  $\lambda$  curves gives a  $d$  vs  $\lambda$  curve. This determines the value of  $\lambda$  associated with a prescribed reference level of damage. With  $\lambda$  known, the  $\tilde{\tau}_i$  are determined and hence from (20), the  $\tilde{b}_i$ . From the  $\tilde{\tau}_i$ 's and the  $\tilde{b}_i$ 's, the combinations

$$4\tilde{x}_i + 10\tilde{y}_i$$

are determined.

The final optimization, of course, involves the interceptor battle. From the above suboptimization,  $\tilde{b}$  and  $4\tilde{x} + 10\tilde{y}$  are known. The problem is now to choose  $b$ ,  $x$  and  $y$  so as to make

$$b \cdot \tilde{\phi}(f) = \tilde{b} \quad (23)$$

and

$$(4x + 10y) \cdot \phi(f) = 4\tilde{x} + 10\tilde{y} \quad (24)$$

with minimum

$$c = b + x + y \quad . \quad (25)$$

Equations (23) and (24) determine  $b$  and  $4x + 10y$  as functions of  $f$ . These and

$$b + 4x + y = f$$

determine  $b$ ,  $x$ , and  $y$  and hence  $c$  as functions of  $f$ . A curve of  $c$  vs  $f$  determines the minimum  $c$ . The associated  $f$  value then fixes the other unknowns in the problem.

The sub-optimization procedure above is valid only when it leads to solutions with all  $y_i > 0$ . If the interceptor force is sufficiently strong vis-a-vis the local defenses,

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this condition may fail. In this event, short-range decoying is unprofitable and the model of the next section should be used to design the attack.

The form used for the SAM assignment function  $\tilde{\phi}$  is that appropriate for a rate-of-fire- or stockpile-limited engagement in which all flying objects are engaged. The calculation of  $m_i$  is based on the probability of kill against the ASM's.

The form of the over-all interceptor assignment function presumes a common experience for objects in the interceptor battle. Otherwise, it is general enough to encompass, for example, several tandem battles of the n-battle random type, each with a different interceptor force brought to bear.

## LOCAL-PLUS- INTERCEPTOR DEFENSE MODEL WITH ONE-STAGE DECOYING

The defining conditions for this model are the same as those of the preceding section except that there are no short-range decoys. Consequently, now

$$\tilde{r}_i = \frac{m_i}{2\tilde{b}_i + 4\tilde{x}_i} ,$$

$$f = b + 4x ,$$

$$\tilde{f} = f \cdot \phi(f) = \tilde{b} + 4\tilde{x} ,$$

and

$$c = b + x .$$

The enemy's problem now is to choose the  $b_i$ 's and  $x_i$ 's to achieve a specified total expected damage for a minimum  $c$ . Considering the local defenses, we seek  $\tilde{b}_i$ 's and  $\tilde{x}_i$ 's which maximize  $d$  for given totals  $\tilde{b}$  and  $\tilde{x}$ . This leads to the marginal utility conditions

$$\frac{\partial d_i}{\partial \tilde{b}_i} = \xi \tag{26}$$

and

$$\frac{\partial d_i}{\partial \tilde{x}_i} = \mu . \tag{27}$$

Substitution of (15) into these conditions, some straight-forward manipulation, and a change of parametric variables leads to

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$$\frac{\tilde{b}_i}{m_i/\chi} = f(\tilde{\tau}_i) \quad , \quad (28)$$

$$\frac{\lambda}{v_i} = \tilde{\phi}(\tilde{\tau}_i) \exp [(-m_i/\chi) g(\tilde{\tau}_i)] \quad , \quad (29)$$

and

$$\frac{d_i}{v_i} = 1 - \exp [(-m_i/\chi) g(\tilde{\tau}_i)] \quad , \quad (30)$$

where  $f(\tilde{\tau}_i)$  and  $g(\tilde{\tau}_i)$  are as defined following Eqs. (20) to (22). Proceeding as in the preceding analogous case, for an assumed value of  $\chi$ ,  $\tilde{b}_i$  and  $\tilde{\tau}_i$ , and hence  $\tilde{b}_i$  and  $\tilde{x}_i$  can be determined. This determines  $\tilde{f} = \tilde{b} + 4\tilde{x}$ .  $f$  is then fixed by

$$f \cdot \phi(f) = \tilde{f} \quad .$$

$c$  is then found from

$$c = b + x = \frac{\tilde{b} + \tilde{x}}{\phi(f)} \quad .$$

Repeating this process for different trial values of  $\chi$  and plotting  $c$  vs  $\chi$  establishes the desired minimum value of  $c$ . From the associated  $\chi$  value, all the other quantities of interest can be determined.

LOCAL-PLUS-  
INTERCEPTOR  
DEFENSE MODEL  
WITHOUT DECOYS

The defining conditions for this model differ from those of the previous section in that there are no decoys. Consequently, now

$$\tilde{\tau}_i = \frac{m_i}{2\tilde{b}_i} \quad ,$$

$$f = b \quad ,$$

$$\tilde{f} = f \cdot \phi(f) = \tilde{b} \quad ,$$

and

$$c = b \quad .$$

The problem is now that of choosing the  $\tilde{b}_i$  to give the desired  $d$  with minimum  $\tilde{b}$ , since this latter will now imply a minimum  $c$ . The marginal utility condition is now simply

$$\frac{\partial d_i}{\partial \tilde{b}_i} = \mu \quad . \quad (31)$$

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Substitution of (15) into (31) gives

$$v_i \exp[-\tilde{b}_i \tilde{\phi}(\tilde{\tau}_i)] \cdot [\tilde{\phi}(\tilde{\tau}_i) - \tilde{\tau}_i \tilde{\phi}'(\tilde{\tau}_i)] = \mu \quad (32)$$

Using  $\tilde{b}_i = m_i/2\tilde{\tau}_i$ , (32) and (15) can be written

$$\frac{\mu}{v_i} = \exp\left\{\left[-m_i \tilde{\phi}(\tilde{\tau}_i)\right]/2\tilde{\tau}_i\right\} \cdot [\tilde{\phi}(\tilde{\tau}_i) - \tilde{\tau}_i \tilde{\phi}'(\tilde{\tau}_i)] \quad (33)$$

and

$$\frac{d_i}{v_i} = 1 - \exp\left[-m_i \tilde{\phi}(\tilde{\tau}_i)/2\tilde{\tau}_i\right] \quad (34)$$

These can be used to plot  $\mu$  vs  $\tilde{\tau}_i$  and  $d_i$  vs  $\tilde{\tau}_i$  for each  $i$ . Cross-plotting then yields first, plots of  $d_i$  vs  $\mu$ , then of  $d$  vs  $\mu$ . Choosing  $\mu$  to give the desired reference value of  $d$ , the  $\tilde{\tau}_i$ 's and thence the  $\tilde{b}_i$ 's are determined. With  $\tilde{b} = \tilde{f}$  known,  $f = b = c$  is determined so that

$$f \cdot \phi(f) = \tilde{f} \quad .$$

## REMOTE AIR BATTLE MODEL WITH DECOYING

Consider a remote air battle (RAB) zone through which the enemy must deliver a force  $c$  of loaded bomb and decoy carriers to use against the contiguous combat system. How, by using a separate stage of long-range decoying, can the enemy minimize the number of carriers he must feed into the remote battle to get the desired force  $c$  out?

Let

$c$  = force of carriers to be delivered through the RAB,

$\hat{c}$  = carriers of type  $c$  entering the RAB,

$z$  = decoy carriers added for use against the RAB only,

$C = \hat{c} + z$  = total force entering RAB,

$h_r$  = defensive kill potential used in RAB.

In the RAB systems evaluated, the duration of the battle was so long, and the fractional attrition exacted against the raids giving  $d = 15$  megadeaths against the interior defenses so small, that the expected number of kills was essentially equal to  $h_r$ . Assume that each decoy carrier used against the RAB system launches 3 decoys of something over 1000 miles range as it enters the RAB zone and accompanies them through that zone, but that neither it nor its decoys enter the interior defenses.

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The expectation of survival of a flying object in the RAB is then

$$\frac{\hat{c} + 4z - h_r}{\hat{c} + 4z}$$

Since it is required that

$$\hat{c} \cdot \frac{\hat{c} + 4z - h_r}{\hat{c} + 4z} = c \quad ,$$

we have

$$z = \frac{\hat{c}}{4} \left( \frac{h_r}{\hat{c} - c} - 1 \right) \quad . \quad (35)$$

From this,

$$C = z + \hat{c} = \frac{\hat{c}}{4} \left( 3 + \frac{h_r}{\hat{c} - c} \right) \quad . \quad (36)$$

To minimize C for fixed  $h_r$  and  $c$ , we choose  $\hat{c}$  to make

$$\frac{dC}{d\hat{c}} = \frac{1}{4} \left[ 3 + \frac{h_r}{\hat{c} - c} - \frac{h_r \hat{c}}{(\hat{c} - c)^2} \right] = 0 \quad .$$

This gives

$$\hat{c} = c + \sqrt{\frac{h_r c}{3}} \quad . \quad (37)$$

Substituting (37) into (35) and (36) and rearranging terms we obtain

$$\frac{z}{h_r} = \frac{1}{4} \left( \frac{h_r}{c} + 2 \sqrt{\frac{h_r}{3c}} - 1 \right) \frac{c}{h_r} \quad (38)$$

and

$$\frac{C - c}{h_r} = \left[ \frac{3}{4} \left( 1 + \sqrt{\frac{h_r}{3c}} \right)^2 \right] - 1 \frac{c}{h_r} \quad . \quad (39)$$

The results of (38) and (39) are valid for  $h_r/c \geq 1/3$ . For  $h_r/c \leq 1/3$ , (38) indicates  $z < 0$  and the optimization is no longer valid. In this range no decoying is profitable so that

$$z = 0$$

and

$$\frac{C - c}{h_r} = 1$$

replace (38) and (39).



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Unless the RAB kills exceed 1/3 of the force to be delivered through the RAB zone, decoying is unprofitable so that the increment in the enemy force required to offset the RAB kills is the same as the number of kills. For  $h_r/c > 1/3$ , decoying reduces the required force increment below  $h_r$ . However, " $(C - c)/h_r$ " as given by (39) falls off from unity rather slowly with increasing  $h_r/c$

$$\left[ \text{e.g., } \frac{C - c}{h_r} = 2/3 \text{ for } \frac{h_r}{c} = 3 \right] .$$

## USE OF MODELS IN LAMP LIGHT SYSTEM EVALUATIONS

The easiest of the system variations analyzed were those in which the SAM's were given no capability against air-to-surface missiles. This falls in the province of the pure area defense model, provided unavoidable overflying of SAM zones en route to ASM launching points is not required. A little testing of attacks on East Coast-plus-Midwest target systems and on East Coast-only systems quickly indicated the latter were superior because of the smaller interceptor force brought to bear. Further variations on the East Coast-only attack soon established the optimum target list for a minimal 15-megadeath attack as:

<u>Aiming Point</u>	<u>Value</u>
New York City (A)	4.1
New York City (B)	4.1
New York City (C)	4.1
Philadelphia	3.0
Boston	<u>2.2</u>
	17.5

These targets are approachable directly from the Atlantic without overflying any SAM defenses of other cities or engaging medium-range interceptors based toward the southern end of the East Coast or in the western part of the heartland.

In the variations where the SAM's were given a capability against the ASM's, the simple interceptor-only model had to be abandoned. However, the insight it had already given expedited the verification that the above target list and approach route was still the enemy's best bet at the 15-megadeath level, because these high-value aiming points were, if anything, underprotected by the SAM allocations presented.

The analyses of cases with an anti-ASM capability and without decoys were made using the local-plus-interceptor model without decoys. The cases with an anti-ASM

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capability and with decoys were first approached with the 2-stage decoying model. A few trials established the fact that the interceptor defenses being assessed were too strong (relative to the SAM defenses) for short-range decoying to be profitable. Hence the more complicated computations of the 1-stage decoying model had to be applied.

The effect on the effectiveness index of adding various remote air battle systems onto several contiguous combat system variations was determined by the RAB model with decoying. The "output force"  $c$  of the RAB was simply the input force defining the effectiveness index of the contiguous system inside it. The differential force  $C - c$  as determined in the preceding section is then the increase in over-all effectiveness index attributable to the addition of the RAB system. In the cases considered,  $h_r/c$  was never large enough to make  $C - c$  less than about 80 per cent of  $h_r$ .

*R.C. Prim*

**CONFIDENTIAL**

**CHAPTER 16  
HISTORY, ORGANIZATION AND OPERATION  
OF PROJECT LAMP LIGHT**

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## CHAPTER 16

### HISTORY, ORGANIZATION AND OPERATION OF PROJECT LAMP LIGHT

The Lamp Light study project originated from the Navy's recognition of the technical problems arising out of plans to employ naval forces in extending the continental air defense system to seaward.

By the end of 1953, planning in the Department of Defense had advanced to a stage where the role of the Navy in extending the shore-based air defense capability into the ocean areas had begun to crystallize. This Navy responsibility would require the operation of various naval units, including radar picket ships and AEW aircraft, in collaboration with Air Defense Command organizations based on the continent. It was evident that the naval units so employed must possess technical equipment for data gathering and communications which would ensure their effective functioning in the over-all plan of defense operations. Such ships and aircraft must be able to operate both with the shore-based commands and with other units of the Fleet and must therefore possess technical compatibility with both at once.

The scientific and engineering work of the Lincoln Laboratory had brought the SAGE System for the Air Force to the stage of development where the Navy could plan its own equipment to be compatible with the future installations on shore. Attention was therefore focused on the Navy's programs for research, development and procurement of equipment to determine whether these special requirements would be satisfactorily met while, at the same time, future equipment would enhance the capabilities of naval forces for performing other naval missions. Although the Navy already had development programs in progress to improve the radar, the communications and the data-handling equipment of its ships and aircraft, these programs required adjustment in three major respects:

In many engineering details, to provide compatibility with the continental air defense system.

In time schedule, to keep the Navy in step with the future operational readiness of the system on shore.

In choice of techniques, to ensure the exploitation of the latest technological advances.

The scope of the technical problems involved and their relationship to existing programs led the Navy to conclude that a comprehensive study, with assistance from competent sources external to the Navy, was required to point the direction which the technical planning in these areas should take. Beginning in January 1954, consideration

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was given to the assembling of a "summer study" group to deal with these problems. About the 1st of April a presentation of the problem and of the proposal to set up the study group was made to the Chief of Naval Operations who thereupon approved the plans for conducting such a project. On 7 April 1954 the Secretary of the Navy issued a definite directive to the Chief of Naval Research to establish a Summer Study Group, similar to the Hartwell Committee of 1950, to assist in formulating a coordinated research and development program in these areas. Copies of this letter were furnished to the Bureaus and Offices of the Navy Department which were principally concerned.

On 7 May 1954 the Chief of Naval Operations addressed a letter to the Chief of Naval Research stating in part that it was "considered of vital importance to evaluate the over-all problem from the standpoint of compatibility with Canadian early warning forces."; that it was desired that "this study group examine the naval problems connected with the collection, evaluation and dissemination of surveillance data from the ocean areas into the Air Defense Command AC&W system"; that "the group should pay particular attention to the necessity of having naval forces so engaged compatible with other naval forces assigned purely naval missions"; and that "this study should be directed toward the earliest partial, and ultimately full, mechanization of data transmission." This letter further stated that "an exploration of the technical and scientific feasibility of intercepting and destroying enemy aircraft approaching the continental United States in the vicinity of the barrier lines should also be undertaken."

Because of the inherent relationship of the proposed study to the continuing program of the Lincoln Laboratory and because of the experience gained by the Massachusetts Institute of Technology in conducting previous similar studies, exploratory discussions of the proposed study were begun by the Chief of Naval Research with representatives of MIT beginning in February. By early May it was decided by the Navy to request MIT formally to undertake the management of this new project. An inquiry was therefore addressed to the President of MIT by the Chief of Naval Research on 12 May 1954 as to his willingness to undertake this task (see Annex 1). From the outset of these negotiations, it was understood that this project was intended to be a study of limited duration which would consider the problem, recommend solutions to as many of its aspects as possible, and then be terminated, leaving the implementation of its recommendations to later action by the Department of Defense.

It was also realized that the scope of the proposed study was such that the interests of the other Services were involved. Discussions were therefore initiated by the Navy

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with the Air Force and Army. The Assistant Secretary of Defense for Research and Development took part in the coordination of the three military departments. On 16 June 1954, negotiations with MIT then still being in a preliminary stage, a meeting was held in the office of the Under Secretary of Defense, attended by the following:

Hon. R. B. Anderson	Under Secretary of Defense
Hon. D. A. Quarles	Asst. Sec. of Defense (R & D)
Hon. H. E. Talbott	Sec. of Air Force
Hon. J. H. Smith, Jr.	Asst. Sec. of Navy (Air)
RADM F. R. Furth, USN	Chief of Naval Research
RADM W. G. Schindler, USN	Asst. Chief of Naval Operations
Maj. Gen. J. E. Briggs, USAF	HQ, U. S. Air Force
Maj. Gen. H. B. Thatcher, USAF	HQ, U. S. Air Force
Mr. Trevor Gardner	Asst. to Sec. of Air Force
Dr. E. R. Piore	Office of Naval Research
VADM E. L. Cochrane, USN (Ret)	MIT
Dr. A. G. Hill	Director, Lincoln Laboratory, MIT
Dr. J. R. Zacharias	MIT

At this meeting the following decisions were reached:

That the Air Force's interest in the proposed study was so great that it would thereafter become a joint Air Force-Navy study project with both Services contributing financial support and the Navy (ONR) acting as the administrative agency.

That the study, although at this time still subject to final acceptance by MIT, should not be conducted by or within the Lincoln Laboratory but in other MIT facilities with support and assistance by the staff of Lincoln Laboratory.

That the Air Force and Navy would jointly outline the general scope of the study, beginning with the Navy requirements already formulated.

During the month of June contract negotiations were begun between ONR and MIT which eventually resulted in Research and Development Task Order No. N5ori-07890. The scope of the study was broadly described by Annex "A" to the Task Order (see Annex 2). The total amount of funds finally allocated to conduct this project was \$415,000. By the time these contract negotiations were begun it had become apparent that time would not permit organizing and launching the project early enough for it to be an actual "summer study" and that it could not in fact start work until the end of the summer.

On 22 July 1954 the Secretary of Defense signed a letter to the President of MIT lending the authority of his office to the support of the study project (see Annex 3). This

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was the final step in the processes of authorizing the project. It was followed at once by specific action to start the work.

On 23 July 1954 a preliminary planning meeting was held at MIT, attended by:

VADM E. L. Cochrane, USN (Ret)	Vice President, MIT
Prof. J. R. Zacharias	MIT
Prof. J. B. Wiesner	MIT
Mr. M. M. Hubbard	MIT
Mr. H. W. Fitzpatrick	MIT
CDR G. Hunter, USN	ONR Project Officer
Dr. C. W. Sherwin	Chief Scientist, U. S. Air Force
Lt. Col. C. N. Nelson	HQ, USAF
Major J. L. Lombardo	HQ, USAF

This meeting discussed a wide range of administrative details. It resulted principally in the allocating of responsibility for action to specific individuals present in order to get the work started. The recruiting of the members of the study group appeared to be the largest single task to be accomplished. Definite plans were made at this time:

To organize a steering committee and hold an early meeting at MIT.

To start the actual study on 20 September.

To assign administration of the project to MIT-Division of Defense Laboratories.

To conduct the study at the Lexington Field Station, an MIT building near the Lincoln Laboratory.

To require Top Secret clearance for all project members.

To start the project off with a series of briefings by appropriate representatives of the Services.

To select and assign a code name to the study.

On 5 and 6 August a meeting of the Steering Committee, under the chairmanship of Admiral Cochrane, was held at MIT, attended by the following:

VADM E. L. Cochrane, USN (Ret)	Vice President, MIT
Dr. J. R. Zacharias	MIT
Mr. M. M. Hubbard	MIT
Mr. D. E. Dustin	MIT
Mr. H. W. Fitzpatrick	MIT
Dr. E. R. Piore	ONR

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CDR G. Hunter, USN	ONR
Dr. C. W. Sherwin	Chief Scientist, USAF
Lt. Col. C. N. Nelson, USAF	HQ, USAF
Lt. Col. W. F. LaHatte, USA	OCS, USA
Lt. Gen. E. R. Quesada, USAF (Ret)	Lockheed Aircraft Corp.
Dr. Brockway McMillan	Bell Telephone Laboratories
Dr. Arnold Nordsieck	University of Illinois
Dr. Leland Haworth	Director, Brookhaven National Lab.
Mr. R. H. Shatz	Cornell Aeronautical Laboratory

This meeting produced the following specific plans in addition to approving those previously made on 23 July:

The project adopted the unclassified name LAMP LIGHT.

Prof. Zacharias was to be Technical Director.

The project would start on 27 September with two weeks of briefings, the first week (with the cooperation of C-in-C, Continental Air Defense Command) to be at Colorado Springs and the second week in Washington or Lexington.

The study would then proceed on a full-time basis until some time in January 1955.

The final report would be submitted in February 1955.

A long list of individual names, representing science, industry and government, was compiled for recruiting study group members and each name on this list was assigned to some one of those present to begin the actual recruiting at once.

There should be representation from Canada, and the Navy members would initiate action through proper channels to authorize this.

It might be desirable to have members from the United Kingdom, and the Navy members would explore the possibility of an official invitation. The U. S. Army would contribute a number of persons as members, selected from various interested Army organizations, such as Ordnance and the Signal Corps.

A tentative agenda for the initial briefings was drawn up.

A meeting of a few prospective members best able to contribute to the study of the techniques of a "remote air battle" was scheduled for 17 August in New York. This group would consist essentially of personnel from a coordinated group of Air Force study contractors who had begun work during the summer of 1954 on the airframe, weapons and control aspects of the "remote air battle." These contractor representatives were to be integrated into Project Lamp Light for the duration of the study.

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The size of the study group, while not definitely prescribed, was planned to be considerably larger than had previously been considered.

During the rest of August, action proceeded to implement these plans, particularly the recruiting of individual members for the study group, the detailed preparations for the initial briefings, and the preparation by MIT of the Lexington Field Station building and the organizing of an administrative staff. About 10 August the plans for the study were disclosed to both the Canadian and British staffs in Washington. Definite arrangements were set in motion to secure participation of Canadian members, both through the Defence Research Board and the Canadian Services. On 17 August twelve persons, representing Air Force, Navy, Bell Telephone Laboratories, Lockheed Aircraft Corporation, and Cornell Aeronautical Laboratory, met in New York at Bell Telephone Laboratories headquarters, to discuss the "remote air battle" and to plan the approach to this subject and the coordination of existing projects in this field in support of Lamp Light. A second meeting of this advance working group was held in New York on 9 September.

By 10 September, plans for the initial briefings had progressed to the point where a change in site became necessary because the attendance list had grown too large to be accommodated by facilities available at Colorado Springs. The first two weeks of the project were therefore re-scheduled. Plans were made to hold the briefings at the Naval Air Station, Norfolk, Virginia, 27 September through 2 October, and in Washington 4-6 October.

On 27 September the project formally got under way at the Naval Air Station, Norfolk. The Commandant, Fifth Naval District, acted as host for the first week. A copy of the schedule of the briefings presented during these first ten days is attached as Annex 4. As indicated, the group moved to Washington for the sessions of 4-6 October.

The Chief of Naval Research, in his remarks at the opening of the first day's session, gave the following description of the scope of Project Lamp Light:

" Project Lamp Light was originally conceived in the Navy as a means of seeking solutions to many technological problems arising from the Navy's probable role in continental air defense. The subsequent participation of all three Services has slightly broadened the original concept, without modifying the objectives of the Navy. It is planned that the study will concentrate upon four principal topics:

The systems of equipment required for data handling.

Other technical problems arising from the seaward extensions of the continental air defense system.

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The technical feasibility of a distant or remote air battle against attacking bombers.

The contribution to anti-submarine warfare which can be made by the same forces assigned missions of air defense in the ocean areas.

"Out of this study, the Navy hopes to receive expert guidance in the selection of mechanized systems of data handling. It is important not only that such systems be compatible, as required, with the systems of other Services ashore, but also that they remain compatible with those of other naval forces. We hope the study group will assist us in selecting, from a great number of existing development projects in this field, those which will best reward our future support. We look for recommendations as to future Navy equipment which may be required for picket ships, air patrols and other units participating in continental air defense missions. With all this, however, it is expected that the study group will recognize the purely naval missions of our fleet units, particularly their offensive capabilities. Any recommendations for the equipping of naval forces for a role in continental air defense must detract nothing from the capabilities of these same units in these primary naval missions."

After these formal briefings were completed, the study group assembled at Lexington on 11 October. It thereafter operated on a full-time basis (9 a.m. to 5 p.m., 5 days a week) through 18 February 1955, except for a total of six days as part of vacations at Thanksgiving and Christmas. The eventual complete membership of Lamp Light and its organization into working groups is shown by Annex 5. The Canadian members participated from the opening date on 27 September. The three British members joined the project on 6 December.

Although the membership roster identifies the usual affiliation of each individual, all the working members of the staff were selected on the basis of their individual qualifications. Each man was recruited by name and not as a representative of his parent organization. Membership was planned so as to form a balanced group with the best technical qualifications obtainable for dealing with the specific subjects to be studied. The principle that each member represented only himself and was expected to contribute freely of his talents with loyalty to this project seemed well understood and unselfishly followed by all members. Nevertheless, it was thoroughly appreciated that all the parent organizations from which the members came made a significant sacrifice in contributing their personnel to the project for a four to five months' period.

Throughout the progress of the study, many other persons contributed their time and knowledge to this study project. A large number of persons visited the Lexington

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Field Station, some of them repeatedly or for several days at a time, to give the study group formal briefings or specific information or to participate in discussions of a variety of topics. A list of all the persons who came as such invited consultants to the project is attached as Annex 6.

Members of the project, singly or in small groups, made numerous visits to other projects, to government contractors, to various agencies of the Armed Services, to scientists and engineers, to Navy ships and Air Force bases, gathering information and holding consultations, which contributed to the mass of information digested by the study group. The project was freely furnished with documents and reports from government sources bearing on the many subjects under study.

The proximity of the Lincoln Laboratory and the cooperation of its Director, Dr. A. G. Hill, and his staff, were important factors in the successful operation of Project Lamp Light. Members of the laboratory staff were constantly available for technical consultation. A small amount of experimental work was performed by Lincoln at the request of Lamp Light to verify new technical ideas. No laboratory work was done by Lamp Light itself.

Local contract administration and security control functions were performed for the Navy by the Boston Branch of the Office of Naval Research, Capt. D. C. Beard, USN, Commanding Officer. Close collaboration between this local Navy office and the MIT staff did much to ensure smooth administration of the project.

Because of the intensive nature and limited duration of such a study project, almost none of its business can be handled on a routine basis. This is particularly true, for example, in processing security clearances for large numbers of individuals. It is even true of the handling of classified mail and special documents. Success is dependent upon a high order of confidence and mutual understanding between the contractor's staff and the military agencies with whom they must deal daily. In the case of this project, the cooperation between MIT and the Office of Naval Research was outstandingly successful. Those with administrative responsibility were keenly aware of the need to keep the working technical members of the study group from being impeded by delays of any sort in arranging for visits, for travel, for the delivery of technical information, etc. While mundane by nature, these details of management are of crucial importance to the success of a high-priority, short-term study of this type. An efficient, cooperative team effort behind the scenes is nearly as essential to success as the quality of the study group itself.

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Much of the work of Lamp Light took the form of day-in and day-out group discussion in an informal atmosphere. These discussions were backed up by individual study on the part of the members. As ideas emerged in the minds of individuals or were threshed out in group discussion, numerous papers were prepared for internal dissemination to exchange ideas within the study group. Thus a considerable body of literature was generated throughout the term of the study. All of this was of a preliminary nature. While much of it forms the basis of this final report, there are many of these preliminary documents which were written for discussion purposes only and which expressed views or made recommendations contrary to those eventually included in the final report.

During the course of the study, two general meetings were held to review progress and diffuse the trend of project thinking to all members. These took place on 19-20 November and on 20-21 December at Lexington. These two-day oral presentations were intended primarily as status reviews for the Lamp Light members themselves. Therefore only a small number of other persons was invited as observers to test the reaction of sponsoring and associated agencies.

During approximately the last month of the study, visitors to the project were reduced to a minimum. All members concentrated at this time on preparation of material for the final report and on resolving divergent points of view in order to incorporate the best possible consensus in the official report.

The concluding major effort of the group consisted of two meetings which were held with large audiences of invited guests, principally representing Department of Defense agencies. These meetings were essentially duplicates of one another and consisted of summaries of the study group's conclusions and recommendations (oral previews of the Lamp Light final report). These presentations were given at the New England Mutual Hall in Boston, on 9-10 and on 15-16 February 1955. Approximately 240 guests attended the first and 280 the second. The following organizations were represented by the audiences:

## Department of Defense

Office of Asst. Secretary of Defense (R & D)  
Agencies of the Joint Chiefs of Staff (WSEG, JCEC, etc.)  
Chief, Armed Forces Special Weapons Project

## Canada

Defence Research Board  
Royal Canadian Navy, Army and Air Force

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## U. S. Army

Army General Staff  
Continental Army Command  
Signal Corps  
Ordnance Corps

## U. S. Navy

Office of the Secretary  
Office of Chief of Naval Operations  
Office of Naval Research  
Bureaus of Aeronautics, Ships and Ordnance and certain  
of their laboratories  
Staffs of Cincpac, Cinclant and various subordinate  
Fleet commands  
Staffs of Comeastseafron and Comwestseafron  
Staff, First Naval District  
Staff, Naval War College

## U. S. Air Force

Office of the Secretary  
Headquarters U. S. Air Force  
Continental Air Defense Command and subordinate commands  
Air Research and Development Command and various  
subordinate centers  
Strategic Air Command  
Air University

## Treasury Department

Asst. Secretary of the Treasury  
Commandant U. S. Coast Guard

Most members of the study group were released on or before 18 February 1955. The actual study work was completed by that date. The reduced number of members who constituted the Editorial Committee then took over the task of editing and preparing this final report.

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## ANNEX 1

/COPY/

ONR:102:hm  
Ser: 0880  
12 May 1954

CONFIDENTIAL

Dr. J. R. Killian, President  
Massachusetts Institute of Technology  
Cambridge 39, Massachusetts

Dear Dr. Killian:

You are aware, through the work of the Lincoln Laboratory and the past studies that you have undertaken for the military departments, that the Navy has responsibility for some aspects of the defense of the continental United States. Apart from the potential submarine threat, there are two other problems: the extension of a possible Canadian early warning line seaward and the possible associated remote air battle at sea, and the seaward extensions of the Lincoln transition system. The technology of these naval responsibilities, both in support of the Air Defense Command and the Navy's direct responsibility, is varied and complex. The several weapon systems must be compatible with forces at sea and forces ashore, whether they are under Navy command or under the command of another service.

Although there is an extensive research and development program in many of the areas outlined above, both the Secretary of the Navy and the Chief of Naval Operations, after careful review, feel that it is necessary to study the engineering problems associated with the compatibility of the Lincoln transition system with the naval forces extending it seaward and the related mechanization of data handling, and the adequacy of the research and development program to determine whether new elements in technology can be brought to bear on these very difficult problems.

With these realizations, both the Secretary of the Navy and the Chief of Naval Operations have asked me to determine whether a study can be initiated, with the participation of some of the best scientific and engineering minds in this country, with the view of strengthening technically the Navy's responsibility in the areas outlined above.

Thus I take this occasion to write to you, being fully aware of the very large contribution that the Massachusetts Institute of Technology is now making in support of the solution of the varied and troublesome problems that the military departments face, to ask you whether you will undertake this additional burden for a limited period of time. I do hope I can get a favorable reply from you.

Sincerely yours,

/s/ F. R. FURTH  
Chief of Naval Research

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## ANNEX 2

CONFIDENTIAL

15 June 1954

### ANNEX "A" TO CONTRACT N5ori-07890

The contractor shall furnish the necessary personnel and shall establish a scientific investigatory group consisting of an appropriate number of scientists and such additional technicians and clerical personnel as may be required. As instructed by the Scientific Officer or his authorized representative, the group shall conduct a study of naval and air problems connected with Continental Air Defense including the mechanization of data handling and the associated systems of equipment and the coordinated employment of these systems. The research shall include, but not necessarily be limited to: (a) a study of the engineering problems associated with the compatibility of the Lincoln "Transition System" with the Naval forces; (b) a study of the seaward extension of the Lincoln system and the related mechanization of data handling; (c) a study of the technical problems involved in a remote air battle; and (d) an intensive study to determine whether new elements in technology can be brought to bear on the above problems.

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ANNEX 3

/COPY/

22 July 1954

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Dear Dr. Killian;

I have been informed that the Department of the Navy has had conversations with you regarding the formation of a group for a limited period of time, in association with the Lincoln Laboratory, to study the engineering and technical aspects of the seaward extension of the continental defense, and to look into what future technology holds in store in this general area. From the review of the problem that I have made, I also feel that we must continually explore improvements in any system that we are now installing and planning to utilize, so that the best in American science and technology is always available to us.

Recognizing that the Lincoln Laboratory is a very large burden and responsibility on your institution, I am reluctant to ask you to assume an additional burden, even for a limited period of time. However, the problem that we are asking this group to undertake is part and parcel of the activities of the Lincoln Laboratory and there is almost no choice, in keeping this general area integrated with a common purpose, but to ask you to undertake this study. This problem is an important element in continental defense and carries the same priority in the Department of Defense as continental defense. The Department of Defense and the three military departments will give you all the necessary cooperation so that you can obtain the best people in American science and technology for this study, and they will also provide any other assistance that may be necessary.

The Department of the Navy has properly taken the initiative in these conversations with you, and the Departments of the Army and the Air Force have been kept informed. I further understand that certain essential agreements as to scope and relationship to the Lincoln Laboratory and related activities were reached at a recent meeting between representatives of the Institute and the Deputy Secretary of Defense, the Assistant Secretary of Defense for Research and Development, the Secretary of the Air Force, and the Assistant Secretary of the Navy for Air. In line with these discussions, I will look to Mr. Donald A. Quarles to see that provision is made for the necessary participation of the three departments.

Sincerely yours,

/s/ CHARLES E. WILSON

Dr. J. R. Killian, Jr.  
President  
Massachusetts Institute of Technology  
Cambridge 39, Massachusetts

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## ANNEX 4

### Project LAMP LIGHT

### Schedule of Briefings

1330 27 September 1954 thru 2 October 1954  
Naval Air Station, Ely Hall, Norfolk, Virginia

<u>Time</u>	<u>Subject</u>	<u>Classi- fication</u>	<u>Speakers</u>
1330 - 27 Sept	Welcome		Adm Ingolf N. Kiland Comdt, 5th Naval Dist
	Statement of Project - Purpose		Adm F. R. Furth
	Chairman - Opening Remarks		E. L. Cochrane Vice Adm (Ret)
1400 - 27 Sept	Introduction	TS	Maj Gen F. Smith
1430 - 27 Sept	The Threat	TS	Brig Gen Burgess
28 Sept a.m.	ADC Briefing	TS	Brig Gen Bergquist
	Forum	TS	Col E. Herbes Col J. Meyer Col H. Neal
28 Sept p.m.	ADC Exercises	TS	Col J. Meyer
	ADC Exercise CHECK POINT Results	TS	D. W. Patterson
	AAA Exercise CHECK POINT Results	TS	Lt Col H. Tyree
	ADC Identification Procedures		Col J. Meyer
29 Sept a.m.	Search radar, present and future	S	Dr. A. G. Hill Director, Lincoln Lab
29 Sept a.m.	Getting maximum information out of search radars	S	Dr. R. I. Hulsizer Univ. of Illinois Control Systems Lab
29 Sept p.m.	AI Radar, present and future	S	Dr. C. W. Sherwin Chief Scientist, USAF
	Inspection of AEW A/C WV-2 and P-2-V		Mr. R. S. Sargent Bureau of Aeronautics
30 Sept a.m.	Data Handling Systems and their capabilities	TS	Mr. J. V. Harrington Lincoln Laboratory Dr. Arnold Nordsieck Univ. of Illinois Control Systems Lab

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<u>Time</u>	<u>Subject</u>	<u>Classi- fication</u>	<u>Speakers</u>
30 Sept p.m.	Identification  Doppler Radar	S	Dr. C. E. Cleeton Naval Research Lab  Dr. J. C. W. Scott Defence Research Board (Canada)
1 Oct a.m.	Navy Status, program and plans; present command doctrine; intelligence	TS	Staff of Chief of Naval Operations
1 Oct p.m.	Capabilities of naval forces; results of air defense exercises	TS	Staffs of CINCLANT, COMAIRLANT COMOPDEVFOR COMEASTSEAFRONTIER
2 Oct.a.m.	Patrol capabilities, ship and air	TS	Dr. Douglas L. Brooks Operations Evaluation Group, Navy Dept.
4-6 October 1954 Pentagon Building Department of the Interior Auditorium Washington, D. C.			
4 Oct 0930 a.m. & p.m.	Guided Missiles	TS	Gen Frederic H. Smith, Jr. Hq CONAD R Adm J. H. Sides CNO (Op-51) Brig Gen K. F. Hertford Army General Staff, G-4 Gen S. R. Brentnall Hq USAF, DCS/O
4 Oct p.m.	CORRODE*		
5 Oct a.m.	Communications	S	Dr. J. B. Wiesner Director, Research Lab of Electronics, MIT
5 Oct p.m.	Attack Capabilities of Naval Interceptors  Datar System	TS	Cdr D. H. Guinn Air Warfare Division OPNAV  Cdr D. L. Hanington Royal Canadian Navy

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<u>Time</u>	<u>Subject</u>	<u>Classi- fication</u>	<u>Speakers</u>
6 Oct a.m.	Interception capabilities and coordination, including airborne CIC	TS	Dr. G. E. Valley Lincoln Laboratory Dr. H. Hall Office of Naval Research
6 Oct p.m.	Interceptors	TS	Dr. H. G. Stever Mass. Inst. of Tech.

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## ANNEX 5

### PROJECT LAMP LIGHT

Allison, Donald M., Jr.	Bendix Aviation Corporation
Bailey, Robert A.	Lockheed Aircraft Corporation
Balchen, Col. Bernt	United States Air Force
Bane, Col. John C.	Office, Chief of Continental Army Command
Bayne, S/Ldr. Robert J.	Royal Canadian Air Force
Brenneman, David E.	Bell Telephone Laboratories
Buhl, Walter T.	Consultant
Cass, Cdr. William F.	United States Coast Guard
Cleeton, Claud E.	Naval Research Laboratory
Cochrange, Vadm. (Ret) E. L.	Massachusetts Institute of Technology
Coltman, John W.	Westinghouse Research Laboratories
Cook, Thomas B.	Sandia Corporation
Crenshaw, Craig M.	Signal Corps Engineering Laboratories
Crowley, Daniel J., Jr.	Air Force Cambridge Research Center
DeTurk, John E.	University of Michigan
Dustin, Daniel E.	Lincoln Laboratory, M.I.T.
Dyke, Walter P.	Linfield College
Edwards, Lawrence K.	McDonnell Aircraft Corporation
Emberson, Richard M.	Associated University, Inc.
Forsyth, Charles M.	McDonnell Aircraft Corporation
Fraser-Harris, Capt. A. B. F.	Royal Canadian Navy
Gardner, Maj. Gen. (Ret) Grandison	Massachusetts Institute of Technology
Garwin, Richard L.	International Business Machines Corporation
Gillette, Dean	Bell Telephone Laboratories
Gray, William L.	Boeing Airplane Company
Griffin, Capt. John H.	Lincoln Laboratory, Navy Liaison Office
Hanington, Cdr. Daniel L.	Royal Canadian Navy
Harman, R. Joyce	Lincoln Laboratory, M.I.T.
Higinbotham, William A.	Brookhaven National Laboratory
Higgins, Thomas P., Jr.	Lockheed Aircraft Corporation
Holmes, William S.	Cornell Aeronautical Laboratory, Inc.
Hopkins, Nigel J.	Defence Research Board, Canada
Hrones, John A.	Massachusetts Institute of Technology
Hubbard, Malcolm M.	Lincoln Laboratory, M.I.T.
Hudson, Colin M.	Office of Chief of Ordnance, U.S. Army
Hunter, Capt. Gould	Office of Naval Research, Project Officer
Hutchins, William R.	Raytheon Manufacturing Company
Jerger, Joseph J.	Raytheon Manufacturing Company
Karns, Charles V.	Operations Evaluation Group
Katz, Leonhard	Woburn Engineering Company
Keilson, Julian	Lincoln Laboratory, M.I.T.
Liddell, Urner	Bendix Aviation Corporation
McCown, Everett E.	Naval Electronics Laboratory
McDonnell, James S., Jr.	McDonnell Aircraft Corporation
McMillan, Brockway	Bell Telephone Laboratory
McNally, Cdr. Irvin L.	Office of Naval Research, Asst. Project Officer
Mehle, Cdr. Roger W.	United States Navy
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Moore, Cordell B.	Convair

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Morris, Frederick W., Jr.	Remler Company, Gray Scientific Division
Nelson, Lt. Col. Conrad N.	USAF, Air Force Project Officer
Nitze, Paul H.	Consultant
Osborn, Palmer	Convair
Overhage, Carl F. J.	Lincoln Laboratory, M.I.T.
Purcell, Edward M.	Harvard University
Patterson, Donald W.	Continental Air Defense Command
Perkins, Kendall	McDonnell Aircraft Corporation
Piore, E. R.	Office of Naval Research
Porter, Arthur	Defence Research Board, Canada
Pretty, Air Cmdre. W. P. G.	British Air Ministry
Prim, Robert C., III	Bell Telephone Laboratories
Quesada, Lt. Gen. (Ret) Elwood R.	Lockheed Aircraft Corporation
Radford, Kenneth J.	Defence Research Board, Canada
Raleigh, Lt. Col. Robert C.	Continental Air Defense Command
Rettie, Richard S.	National Research Council, Canada
Robie, Col. John W.	Joint Air Defense Board
Rochester, Nathaniel	International Business Machines Corporation
Rollefson, Ragnar	University of Wisconsin
Salisbury, Winfield W.	Remler Company, Gray Scientific Division
Sarell, Capt. R. I. A.	British Admiralty
Schultz, Jack L.	General Electric Company
Scott, James C. W.	Defence Research Board, Canada
Selfridge, Oliver G.	Lincoln Laboratory, M.I.T.
Shatz, Robert H.	Cornell Aeronautical Laboratory, Inc.
Shepard, Capt. Evan T.	United States Navy
Silverberg, Thomas R.	Raytheon Manufacturing Company
Stevenson, Donald T.	Lincoln Laboratory, M.I.T.
Stevenson, Lt. Col. Robert J.	Continental Air Defense Command
Stieber, Alexander	Cornell Aeronautical Laboratory, Inc.
Sunstein, David E.	Philco Corporation
Van Voorhis, Stanley N.	Lincoln Laboratory, M.I.T.
Waddell, Mathews C.	Applied Physics Laboratory
Watson, D. Stewart	British Admiralty
Wiesner, Jerome B.	Massachusetts Institute of Technology
Woonton, Garnet A.	McGill University
Zacharias, Jerrold R.	Massachusetts Institute of Technology
Zahl, Harold A.	Signal Corps Engineering Laboratories

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## PROJECT LAMP LIGHT WORKING GROUPS

### Radar

Woonton, G. A.  
Allison, D. M.  
Coltman, J. W.  
Crowley, D. J.  
Schultz, J. L.  
Silverberg, T. R.

### Counter-Countermeasures

Sunstein, D. E.  
Keilson, J.  
Morris, F. W.  
Pretty, W. P. G.  
Salisbury, W. W.  
Scott, J. C. W.  
Watson, D. S.

### Data Processing

Wiesner, J. B.  
Higinbotham, W. A.  
Cleeton, C. E.  
DeTurk, J. E.  
Garwin, R. L.  
Hanington, D. L.  
Holmes, W. S.  
McCown, E. E.  
McNally, I. L.  
Porter, A.  
Rochester, N.

### Aircraft

Forsyth, C. M.  
Bailey, R. A.  
Gray, W. L.  
Moore, C. B.  
Shatz, R. H.

### Communications

Wiesner, J. B.  
Crenshaw, C. M.  
Garwin, R. L.  
Scott, J. C. W.  
Sunstein, D. E.  
Zahl, H. A.

### Air Defense Systems

Bailey, R. A.  
Hrones, J. A.  
Bane, J. C.  
Bayne, R. J.  
Edwards, L. K.  
Forsyth, C. M.  
Gillette, D.  
Higgins, T. P.  
Hopkins, N. J.  
Mehle, R. W.  
Moore, C. B.  
Raleigh, R. C.  
Robie, J. W.  
Shatz, R. H.  
Stevenson, R. J.  
Stieber, A.

### Navigation, Identification

Wiesner, J. B.  
Buhl, W. T.  
Cleeton, C. E.  
Crenshaw, C. M.  
Crowley, D. J.  
Garwin, R. L.  
Holmes, W. S.  
Sunstein, D. E.  
Zahl, H. A.

### Weapons

Hudson, C. M.  
Bane, J. C.  
Cook, T. B.  
Higgins, T. P.  
Hutchins, W. R.  
Jerger, J. J.

### Evaluation

Gardner, G.  
Prim, R. C.  
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Gray, W. L.  
Karns, C. W.  
Merchant, W. J.

### Evaluation (Cont.)

Osborn, P.  
Patterson, D. W.  
Radford, K. J.  
Waddell, M. C.

### Early Information and Sea Threat

Dyke, W. P.  
Balchen, B.  
Brenneman, D. E.  
Cass, W. F.  
Fraser-Harris, A. B. F.  
Griffin, J. H.  
Hopkins, N. J.  
Hubbard, M. M.  
Katz, L.  
Liddel, U.  
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Shepard, E. T.  
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deBettencourt, Joseph T.	Lincoln Laboratory
Denton, Cdr. James B.	Bureau of Ships
Dibos, Richard A.	Philco Corporation
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Dietzold, Robert L.	Bell Telephone Laboratories
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Sargent, Robert S.	Bureau of Aeronautics
Schechter, Harry	Lincoln Laboratory
Searle, Campbell L.	M. I. T.
Shamp, David J.	General Electronics Inc.
Shannon, Capt.	Fleet Air Wing, U. S. Atlantic Fleet
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Walsh, John E.	Lockheed Aircraft Corp.
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Weiss, Herbert G.	Lincoln Laboratory
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Westcott, James P.	Philco Corporation
Wheeler, Myron S.	Westinghouse Electric Corporation
Whitcraft, W. A., Jr.	Raytheon Manufacturing Co.
White, Wayne B.	Rand Corporation
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Wiseman, W/Cdr. J. A.	Royal Canadian Air Force
Wolf, R. A.	Cornell Aeronautical Laboratory
Wood, Cdr. R. H.	C. O., Naval Air Development Unit, So. Weymouth, Mass.
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Wright, Sir Charles	Marine Physics Lab., San Diego, Calif.
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Zimmerman, C. L.	HQ, Strategic Air Command
Zuckner, F. J.	Air Force Cambridge Research Center

February 24, 1955



DEPARTMENT OF THE AIR FORCE  
WASHINGTON, DC



3 September 2008

HAF/IMII (MDR)  
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Washington, DC 20330-1000

Department of the Navy  
Naval Research Laboratory  
ATTN: Vicki L. Cicala  
4555 Overlook Avenue SW  
Washington, DC 20375-5320

Dear Ms. Cicala

Your letter dated 9 January 2008, requesting a Mandatory Declassification Review of the following documents:

- S 30 921 Final Report of Project Lamp Light, Vol I DTIC AD0311318
- S30922 Final report of Project Lamp Light, Vol II DTIC AD0311319
- S30923 Final Report of Project Lamp light, Vol III DTIC AD0311320
- S30924 Final Report of Project Lamp Light, Vol IV DTIC AD0311321

The appropriate Air Force agency has reviewed the documents IAW the Executive Order 12958, as amended, and finds we have no objection to the declassification and release of the Air Force information.

Address any questions concerning this review to the undersigned at DSN 223-2560 or COMM (703) 693-2560 and refer to case number 08-MDR-040.

Sincerely

  
 JOANNE MCLEAN  
 Mandatory Declassification Review Manager

1 Atch  
Documents for Review (S)



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