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REPORT OF A BOARD CONVENED BY
THE COMMANDER IN CHIEF
U. S. PACIFIC FLEET,
TO MAKE RECOMMENDATIONS ON
RADAR AND COUNTERMEASURES
BASED ON EXPERIENCE
IN THE WAR WHICH RESULTED
IN THE DEFEAT OF JAPAN

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REPORT

1. INTRODUCTION

The purpose of this report is to provide a detailed analysis of the data collected during the experiment. The data was collected over a period of six months, from January to June 1998. The experiment was designed to investigate the effects of various factors on the rate of reaction. The factors studied were temperature, concentration, and catalyst. The results of the experiment are presented in the following sections.

2. EXPERIMENTAL PROCEDURE

The experiment was carried out in a laboratory setting. The reaction was monitored using a colorimeter. The reaction mixture was prepared by combining a solution of reactant A with a solution of reactant B. The temperature of the reaction mixture was controlled using a water bath. The concentration of the reactants was varied by changing the volume of each solution. The catalyst was added to the reaction mixture in a separate step. The rate of reaction was determined by measuring the change in absorbance over time. The data was recorded in a table and plotted on a graph. The graph shows that the rate of reaction increases with increasing temperature and concentration. The catalyst also increases the rate of reaction.

The results of the experiment are summarized in the following table. The table shows the rate of reaction for different temperatures, concentrations, and catalysts. The rate of reaction is highest at 40°C, 0.1M concentration, and with the catalyst. The rate of reaction is lowest at 20°C, 0.05M concentration, and without the catalyst. The data indicates that the reaction is first order with respect to reactant A and second order with respect to reactant B. The activation energy of the reaction is 50 kJ/mol. The catalyst lowers the activation energy of the reaction.

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Serial 604561

UNITED STATES PACIFIC FLEET
AND PACIFIC OCEAN AREAS
HEADQUARTERS OF THE COMMANDER IN CHIEF**DECLASSIFIED**
SECRET

3 DEC 1945

From: Commander in Chief, U. S. Pacific Fleet.
To: Chief of Naval Operations.

Subject: Report of Radar and Countermeasures Board, Forwarding of.

References: (a) CNO Conf. Ltr. Serial 02560 dated 30 August, 1945.
(b) Cincpac Conf. Ltr. Serial 033346 dated 5 Oct., 1945.
(c) CNO Secret Ltr. Serial 00139625A dated 4 Oct., 1945.

Enclosures: (A) Copy of reference (b).
(B) Senior Member Radar and Countermeasures Board Conf. Ltr. dated 6 Nov., 1945 (Report of the Board).

1. In accordance with reference (a), a board of officers was convened by reference (b) to consider matters set forth in references (a) and (b) and to submit a report thereon. (Enclosure (B)).

2. This report is considered to express the consensus of Pacific Fleet opinion while the experiences of the recent war are still fresh in mind, and has the concurrence of Cincpac subject to comments and recommendations inserted on separate pages in the body of the report. In order to permit ready comparison, Cincpac remarks appear opposite related sections of the report with corresponding paragraph numbers.

3. In connection with this report, it is desired to emphasize the necessity for continued research, development and testing in service, vigorously prosecuted in an effort to provide electronic equipment for the Navy and other Armed Forces of the United States superior to that of any other nation. Only by such continuous effort in this, as well as other fields, can we expect to maintain the condition of readiness vital to our National Security.

4. It is recommended that this report with the related comments inserted by Cincpac be used as a basis for planning until such time as further analysis, study, and experience clearly indicate the necessity for pursuing a different course.

5. Reference (c) was considered by the board after it had submitted its report. It is in general accord with the report of the board

QB

Serial 004531

UNITED STATES PACIFIC FLEET
AND PACIFIC OCEAN AREAS
HEADQUARTERS OF THE COMMANDER IN CHIEF

3 DEC 1945

SECRET

Subject: Report of Radar and Countermeasures Board, Forwarding of.

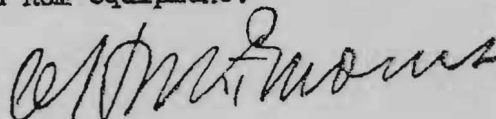
and Cincpac's comments. Certain recommendations set forth in this report are not included in reference (c) and consideration should be given to initiation of the necessary additional projects. Important items on which research and development should continue are listed below and covered in more detail in the body of this report:

(a) Continue efforts to reduce size and weight of all radar and associated equipment.

(b) Continue development of airborne CIC and its supporting radar.

(c) Continue research and development on IFF equipment.

(d) Continue research and development on RCM equipment.



C. H. McMORRIS
Chief of Staff

Copy to: (W/Encls.)

Com3rdFleet

Com5thFleet

Com7thFleet

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CinClant (5)

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ComSubPac

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ComServPac

ComTraComPac

CNO (100 copies for distribution within the Navy Department and shore establishments as desired.)

UNITED STATES FLEET
Headquarters of the Commander in Chief
NAVY DEPARTMENT
Washington 25, D.C.

FF1/All

Serial 02560

30 August 1945

CONFIDENTIAL

From: Commander in Chief, United States Fleet
and Chief of Naval Operations.
To: Commander in Chief, U. S. Pacific Fleet.
Subject: Reports on and Evaluation of Specific Subjects
as the Result of War Experiences.

1. During World War II the Pacific Fleet rendered valuable services through its recommendations on gunnery matters, equipment, radar, ship types, and all forms of endeavor which resulted in the defeat of the Japanese.

2. In order that the Navy may profit from the knowledge gained through the use of the tools of war supplied the Fleet, it is essential that this knowledge be recorded for study and evaluation. This information will be the basis for postwar procurement, development and firm procedures in the use of the material which is now in operation. Therefore, it is desired that evaluated reports be submitted on the following subjects:

- (a) Ammunition, including bombs and fuzes. Torpedoes.
- (b) Radar including countermeasures.
- (c) Ships and aircraft types including landing craft.
- (d) Radio equipment.
- (e) Fire control and armament grouping.

3. Under the applicable subjects listed in paragraph two, the following should be considered in the report:

- (a) Does the material under discussion properly serve the purpose for which it was designed?
- (b) Are there recommendations for
 - (1) Changes and new types?
 - (2) New requirements and new characteristics?
 - (3) Standard installations?
 - (4) Changes in equipment and armament?
 - (5) Changes in present ship types, aircraft types, and landing craft types?
 - (6) Discontinuance of certain ship types, aircraft types, and landing craft types?
 - (7) Standard ship types, aircraft, and landing craft, including the armament and equipment to be installed?

Enclosure (A)

FF1/All

Serial 02560

UNITED STATES FLEET
Orders of the Commander in Chief
NAVY DEPARTMENT
Washington 25, D.C.

30 August 1945

CONFIDENTIAL

Subject: Reports on and Evaluation of Specific Subjects
as the Result of War Experiences.

- (8) Engineering installations, auxiliaries, fire fighting and salvage equipment?
-) Armament grouping to meet the flexibility in fire control required in modern warfare?
- (10) New fire control characteristics?
- (11) Alterations which will improve the flexibility of equipment now installed?

4. As requested by the Commander in Chief, U. S. Pacific Fleet, ship's organization changes have not been made during World War II. However, the question of a modernized ship's organization to fit the administration of the ship types of the Fleet has arisen. Radar, CIC, extensive use of voice radio, and technical advances all have brought forth the need for an administrative organization to fit the new conditions. Recommendations in connection with an Operations Department, a Communication Department, and the need for a revision of the conditions of readiness for action have all stressed the necessity for an extensive study and report on ship types along the lines of this discussion.

5. It is appreciated that the wide dispersion of ships and the indefinite status during demobilization of ships and personnel may create difficulties in constituting Boards within the Fleet to handle these details. It is believed however that by assigning the preparation of these reports to the staffs of Task Fleets, Forces, and Groups not employed in operations that their submission is practicable.

6. It is the present intention of the Commander in Chief, United States Fleet and Chief of Naval Operations to promulgate these recorded Fleet views to the Offices, Bureaus, and Boards (i.e. the Ship Characteristics Board) of the Navy Department in order that they may be used as a basis for future development of equipment and ship characteristics in the postwar Navy. With this explanation in mind it is desired that the Commander in Chief, U. S. Pacific Fleet express his views fully on all reports submitted prior to submission to the Commander in Chief, United States Fleet and Chief of Naval Operations.

/s/ E. J. KING

Copy to:
All Bureaus and Offices
of the Navy Department.

Enclosure (A)

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Part I.

Summary and Recommendations.

1. This board has studied and discussed CNO Secret Serial 00140225A of 8 October 1945, Subject: Radar and CIC Long Range development of for air problems. This Board strongly concurs in the general statements therein and considers the letter an excellent statement of existing problems and the requirements for their solution. Some disagreement with paragraph 4(e) of the above letter is expressed in this report, Part II, Section J, paragraph 2, on IFF development. Radar and IFF development should be coordinated and carried out simultaneously.

2. This Board considers that one of the most vitally necessary post-war projects is the development of an effective search radar for use in airborne radar pickets. It is recommended that development of an efficient airborne radar picket and CIC be vigorously carried on. It is further recommended that Commander Air Support Control Units, Pacific, be included in the commands concerned with service trials and training of prototypes of airborne radar pickets and CIC's.

3. The internal organization of many of our large ships requires improvement to better coordinate the functions of CIC and the use of new electronics devices with the functions of the various standard departments and their equipments. The question of establishment of an operations department in some types of ships should be reviewed and several types of improved organizations should be given further service trials if the operations department is not favored at this time.

4. Ship Borne Surface Search Radar. The SG-b and the SG-lb radars (having Mod. 50) with the desirable features of sensitivity time control, fast time constant circuits, and expandable sweep are considered very satisfactory equipments for the present and for the immediate future. The later series SG radars with higher frequency and standardized construction will satisfy all fleet needs for the near future. The SL series can be considered obsolete and should be replaced with the much better SU

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series radars. The later SO series is considered satisfactory for the needs of the present and near future. It is recommended that the SG-b and SG-1b be retained on ships of the inactive fleet and that the later model SG radars be installed on ships of the active fleet. It is also recommended that one of the late SU series or late SO series be installed wherever possible for small ship surface search use. Future development should be directed toward reduction of size and weight and standardization of components. Improved resolution is also very desirable for surface search radars.

5. Submarine Surface Search Radar. The model SJ series, surface search and also fire control radar, performed well, but is now obsolete. It is recommended that it be replaced by the model SS series on all active submarines, and that it be retained on all inactive submarines. The model ST series, surface search and fire control periscope radar performed well. It is recommended that it be retained in all active submarines, and in as many of the inactive submarines as have it installed at the present time. Improvements are needed in the near and foreseeable future to narrow the beam pattern in azimuth, improve the range and improve the resolution.

6. Shipborne Air Search Radar. None of the air search radars now installed are considered satisfactory in performance for the near future, or foreseeable future in active ships. However, continued development of the SR series will, it is believed, result in a good air search radar for use in the near future until a radically improved air search radar can be produced. The SR-5 or the higher frequency models SR-3 and SR-4 seem to be the most promising. (Refer to II-B-6). The major faults of equipments now in use are: Poor maximum range, poor bearing resolution, large fade zones, no high angle coverage, too low frequency, troublesome antenna pedestals, inadequate shock mounting and difficulty of maintenance. It is considered necessary that the radar of the foreseeable future must overcome the above mentioned difficulties and have the following additional features:

- a. A moving target indicator system.
- b. Stabilized antennas where ship type installation requires.

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- c. Provisions for zenith search.
- d. More rugged and simple antenna pedestal.

In view of meeting the needs of the near future it is recommended that the late model higher frequency SR type air search radars be used to replace all SC/SK radars on all ships of the active fleet insofar as production and present supply permit. This is deemed advisable because the SR series has inherently good design, is standardized, and with future modifications it may become the air search radar to suit the needs of the foreseeable future. SR types should be installed on CV-9 class carriers in the inactive reserve.

7. Submarine Air Search Radar. Submarine air search radars such as the SD series and SV series have not given very good ranges on air targets (15 - 20 miles). The SD series with the non-directive antenna is not considered satisfactory for either present or future use as a submarine air search radar. It is recommended that the SD series be replaced by the SV series on active submarines and the SD-5 be retained on inactive submarines. It is also recommended that steps be taken to improve the range and coverage of the SV series radars. In the near and foreseeable future the antenna should be improved to give information of position angle of contacted aircraft.

8. Zenith Search Radar. The methods used during the latter part of the war to provide zenith coverage were interim measures in an effort to provide immediate protection against high angle air attack. The SG with the zenith search reflector was not satisfactory. The trials of SCR 720-B show that this device is a trend in the right direction. It is recommended that a similar device using spiral scan, having a 40 degree to 90 degree coverage, and a method of presentation giving range, bearing, and position angle be developed specifically for the use of zenith search. This zenith search radar should have its controls adjacent to the air search radar and have its presentation alongside that of the air search radar. The need for an effective zenith search radar has been much discussed in action reports and is keenly felt.

9. Control of Interception Radar. The SP/SM radars have partially satisfied fleet needs during the war. With improvements outlined in paragraph II-B-7 of this report they should be retained for the present and near

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future until a better type is available. The fleet needs a greatly improved intercept radar with greater range, better altitude determination, better resolution, and simplified construction. From data available on the SX radar, which will be capable of dual purpose search and control of interception, it is believed that this radar may satisfy the intercept radar needs of the carriers and battleships in the near future. However, general fleet opinion seriously questions the advisability of depending on one equipment for multiple purpose use since a failure means complete loss of radar data.

10. Surface Fire Control Radar. The performance characteristics of the most recent fire control radars, such as the Mark 12 Mod. 1 and the Mark 13, are considered satisfactory for surface fire control use in the present and near future and it is recommended that the Mark 13 be installed in all new construction Battleships and Cruisers and that it be used to replace the Mark 8 radar on ships of the present active and inactive fleet. It is also recommended that the Mark 12 Mod. 1 be retained for dual purpose fire control purposes on all ships of the active and reserve fleet until Mark 25 equipment is available. The surface fire control radar of the foreseeable future should have the following characteristics:

- a. Maximum range well beyond the effective maximum gun range.
- b. Bearing accuracy consistent with the inherent deflection dispersion of the gun battery (1 - 3 mils).
- c. Resolution as high as possible in range and bearing.
- d. Spotting provisions for range and deflection. Class "B" presentation satisfies this requirement.
- e. The presentation should be as similar to optical as possible. Class "B" presentation partially satisfies this requirement.
- f. Provision for complete automatic tracking and computer aid circuits.
- g. The carrier output frequency should be as high as possible without suffering excessive interference from atmospheric disturbances.

COMMENT BY CINCPAC

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10. Concur in general. Specific reference to Mark 25 should not be taken as an indication that this is the ultimate in "Dual-purpose 5 Inch Fire Control Radar." If a better director and radar system, such as the projected Mark 56 system, proves to be more effective and otherwise satisfactory, then it should be considered for replacement of current systems.

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h. The equipment must be effectively shock mounted.

i. The maintenance problem must be made as simple as possible. (For elaboration on characteristics see paragraph II-C-1.) The only equipments which have approached a really satisfactory surface fire control design are the Mark 13 and Mark 25. It is believed that the Mark 25 with the features of complete automatic tracking, high resolution, and good range may meet the needs of the foreseeable future if it proves satisfactory after trial in the fleet.

11. Anti-Aircraft Fire Control Radar. The performance characteristics of the most recent anti-aircraft fire control radars such as the Mark 12 Mod. 1 - Mark 22 combination, and the Mark 34 Mod. 2/4 are considered satisfactory for anti-aircraft fire control use in the present and near future. It is recommended that:

a. The Mark 12 Mod. 1 - Mark 22 combination be retained on all ships of the active and inactive fleet until such time as a new equipment is developed which will satisfy the basic requirements for the fleet as set forth in section II-C-3.

b. If the Mark 33 director is replaced, the Mark 28 Mod. 0/3 be replaced by the Mark 12 Mod. 1 - Mark 22 combination if weight and space conditions permit.

c. The Mark 28 Mod. 2/4 be replaced by the Mark 34 Mod. 2/4 on ships of the active fleet but retained on ships of the inactive fleet. (Refer to paragraphs II-C-4b, c, d, e for more elaborate discussion).

12. The Anti-Aircraft Fire Control Radar of the foreseeable future must have the following characteristics:

a. Maximum range well beyond the maximum effective range of the gun battery.

b. Bearing accuracy consistent with the inherent deflection dispersion of the gun battery (1 mil or better).

c. Position angle accuracy the same as that for bearing.

d. Provision for a moving target indicator system.

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e. The resolution must be as high as possible in range, bearing and position angle.

f. Provisions for rapid and efficient means of target acquisition.

g. Spotting provisions in range, deflection, and elevation. Class "B" and "C" presentation are desirable.

h. The presentation should be as similar to optical as possible. Class "B" and "C" presentation partially satisfy this requirement.

i. Provision for complete automatic tracking and computer aid circuits.

j. The carrier output frequency should be as high as possible without suffering excessive interference from atmospheric disturbances.

k. The equipment must be effectively shock mounted.

l. The maintenance problem must be as simple as possible. (For more elaborate information see paragraphs II-C-3 a to l.) It is believed that the Mark 25 radar, which is now under contract, will meet the needs of the foreseeable future in most respects providing trials in the fleet prove it satisfactory.

13. Submarine Fire Control Radar. The requirements of the submarine are for an all around fire control radar for torpedo as well as gunfire control. This requires a radar which is capable of giving accurate bearings, long range, and having a type of presentation that is suitable for spotting. It is believed that the Model SS-1 with the desirable features of high resolution and accuracy, great range, and provision for class "A" and "B" presentation will meet the needs of the present, near future and foreseeable future as a good submarine all round fire control radar. It is recommended that the Model SS-1 replace the Model SJ on all active submarines and that the SJ be retained on inactive submarines for training purposes until production volume will enable them to be replaced by the Model SS-1. A radar repeater is needed in the integrated fire control system now being developed on the USS SEA LEOPARD. The

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1. Continued effort to produce a satisfactory IFF system is recommended. Detailed comment will appear opposite the detailed comment in the report.

2. Experimental projects in progress in both AEW and Airborne CIC prior to war's end should be continued.

3. Cincpac recently concurred with CNO in the establishment of a Communications Department. Further comment on this subject was forwarded in Cincpac Restr. Ltr. Ser. 8840 of 30 Aug., 1945. Further reorganization is not recommended until additional study makes clear its necessity.

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12. 1. Mark 25 Radar.

If a better radar and director system, such as Mark 56 projected system, proves to be more effective and otherwise satisfactory, the fleet should have it.

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Model VH is now on the allowance list of active submarines for this purpose. It is not recommended for installation on inactive submarines. (For further information refer to paragraphs II-C-6 a, b, c and II-C-5 a-i.).

14. The long range airborne radar picket and CIC is of greatest importance to provide for long range warning and interception of any attacking force before the enemy can reach his objective. The development of a satisfactory airborne radar picket is considered the most important of all post-war projects and it is recommended that it be pushed with the utmost vigor.

15. Airborne Radar. There should be as few different types of airborne radar systems as practicable. Recommended is one system for light - fast land based patrol aircraft, one system for the slower-heavier patrol craft, and one type, if possible, for carrier based aircraft. In the design of carrier based aircraft radar the following factors must be considered: Streamlining, light weight, tropicalization, moisture proofing, and standardization of parts and equipments. Design should be continued to develop sea-suppressor circuits, automatic frequency control, and moving target indicators which will permit differentiation between land mass or sea return, and moving targets.

16. Shore Based Radar. It is recommended that Marine Air Warning and Fighter Director Units be maintained. They should be coordinated or integrated with Landing Force Air Support Control Units to form a unified air control center to be set up ashore immediately after an assault landing or on any island or coastal territory which might be siezed. These units should use Army type radars and be able to work immediately with Army A. W. and Fighter Director Units and Air Control Centers. These units should also be frequently drilled in coordination with Fleet and Amphibious Force CIC and Air Control Centers afloat. Joint Air Warning reporting and Fighter Control procedure and communication frequencies should be agreed upon, maintained, and adhered to by all concerned. In no other field is instant and efficient Joint Action so vital.

17. Aircraft Early Warning Equipment. The present AEW system is considered inadequate because of the limited range of the radar employed, inability to detect targets over land, and excessive sea return. A high-

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17. AEW presently installed shows sufficient promise to justify continuation of its development and trial in the fleet. It is considered that there is a definite need for both AEW and the Airborne CIC. Accordingly, further development and trial of both these methods is recommended in an effort to provide greatly extended range of effective radar defense for the future. Furthermore, the Airborne CIC gives promise of our eventually being able to exercise real tactical command of large forces of aircraft on distant missions, a most important desideratum. During the war we attempted to do this through the use of Air Group Commanders and Air Controllers. As these officers had available very limited facilities for obtaining information and for the issuance of orders, these efforts to exercise command in the air had very limited success. The Airborne CIC may point the way to true airborne command and the ability to exercise control over wide-spread air action at great distances from carriers or other bases. It should be strongly pushed with this in mind.

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powered airborne radar must be developed which will detect single small aircraft targets at ranges in excess of 100 miles over land. The remote control and television aspects of AEW are of very dubious value. Full operation of radar and CIC in the airplane with voice radio transmission of information to those concerned is simpler, more reliable, less confusing and fully adequate.

18. Ground Controlled Approach Equipment. This Board recommends that all major air bases be equipped with GCA equipment as soon as available and in addition that all minor bases which encounter weather minimums below 500ft. ceiling, or 2 mile visibility, or both, for periods exceeding 5% of the year be so equipped when practicable. This Board concurs with the requirements set forth in the CNO Conf. ltr. Op-25 Ser. 0138125A of 28 September 1945 for the procurement of GCA equipment for CV(N) night carriers.

19. Radar Beacons. It is considered that the development and use of radar beacons should be continued. The present radar beacons need redesigning to increase accessibility of chassis, to facilitate ease of maintenance and operation, and to reduce size and weight.

It is recommended that development of radar beacons be continued to provide:

a. Picket vessels including submarines, aircraft carriers, and seaplane tenders with beacons to respond to airborne radars.

b. Land based beacons at airfields, prominent shore line land marks, and other points as necessary for navigation of air and surface craft.

c. Floatable beacons to respond to shipboard radars to be supplied in life rafts, or for dropping by aircraft to mark location of survivors or the projected track of enemy craft.

d. Lightweight ultra-portable fire control beacons to assist in shore bombardment by radar controlled batteries.

20. IFF Equipment. The present Mark III IFF system, despite its many limitations and undesirable features, has served the fleet well during the Pacific war.

COMMENT BY CINCPAC

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18. Cincpac concurs with the need for GCA equipment. It has proved its worth. However, its application requires an increase in total personnel wherever it is used. Two officers and 7 men are necessary for "on call" service, and about 4 officers and 21 men for "round the clock" operation.

19. Cincpac concurs in the continuation of development of radar beacons. However, during the recent war, radar beacons have not always been enthusiastically received in the Pacific. Caution is enjoined in the expenditure of funds for large quantity production of these devices except when the need for them is definitely established. Improved and more reliable beacons will probably earn a more general acceptance.

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Nevertheless, it is considered to be totally inadequate for future use. The most important of its many faults are: unreliability; poor discrimination in range, bearing, and elevation; the special knowledge required for proper servicing; poor security; and inability to distinguish between different groups of friendly targets.

21. The fleet requires an IFF system which will be reliable, which will inspire the confidence of fleet personnel, and which will have a coding device that will give automatic identification and yet can be readily changed when the original system has been compromised. The presentation of IFF signals on indicators should be so simple and obvious that mistakes and delays, occasioned by the necessity for close examination and lengthy thought processes on the part of operators, will be eliminated. It is therefore recommended that the entire IFF program be reviewed, and that the several new avenues of approach which are now open to use be investigated as soon as possible.

22. Consideration should be given to the following in developing a new IFF system:

a. Varied modulation of pulses of own radar transmitters can be provided so that vessels, at their own discretion, may establish their identity to friendly RCM intercept through the characteristics of their search and intercept radar transmissions.

b. The incorporation of IFF intercept features in RCM installations seems advisable and is practicable.

c. The use of higher IFF frequencies would reduce antenna sizes and improve directional characteristics.

d. The use of coded pulse-time or other modulation features superimposed on both radar and IFF signals appears practicable as a means of automatically discriminating between friend and foe and among different groups of friendly targets and as a means of obtaining additional security.

e. The incorporation of directional IFF as an integral part of each air-search, surface-search, and fire-control radar systems is necessary and practicable.

COMMENT BY CINCPAC

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21. Cincpac concurs in the acute need for an effective IFF system. It should be positive, secure, and as simple as possible in its interpretation and in the technical knowledge required to operate and maintain it.

22. All of these and any other promising possibilities should be exhausted in the search for a good IFF system. Research on this project must be continued. In a future war, compromise may make necessary complete changes of system. Therefore, a basic system, and at least one reserve system, should be provided for any future emergency.

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23. This Board strongly recommends that the development of IFF along the lines indicated herein be vigorously carried out concurrently with or as a part of the development of new radars.

24. Countermeasures. Research and development to improve countermeasures methods and equipment should be carried on. Our present equipment should be redesigned, unified as to racks or cabinets and power supplies, simplified and made more flexible. Improved directional intercept receivers are required. Better radar jamming and radar deception equipment is needed. Better means of directing or nullifying electronically guided or controlled missiles are needed. It is considered that RCM activities should be a part of or controlled by CIC. Our ships and aircraft should make continued and determined efforts to intercept strange electromagnetic wave radiations in all parts of the world. Knowledge of what other nations are doing is vital in this field.

25. Allowances. This Board considers the allowances of radar equipment as given in the Radio Type Allowance Booklet (RE 11A 100) for the various classes of ships reasonably adequate for the immediate future except for the need for Zenith Search Radars. Minor changes to this allowance to meet the conditions of the near future are discussed in Part III of this report. Radars of radically improved characteristics will be required to meet operational conditions of the foreseeable future and will probably entail considerable revision of present allowances.

26. Standardization of Units and Components. The necessity for crash production and development of radar during the war and the many different companies producing the set brought about a situation wherein the many different types of sets bore little resemblance to one another even though they were produced to perform the same function. Some attempts to standardize components have been made with the SR series and the later SG series.

27. This Board considers that further standardization is mandatory and recommends that the best circuits as proved by experience be accepted as standard and that new radars developed with radically improved performance be built around these standard circuits. Construction might be resolved into a series of about six radars, three surface search and three air search to meet the varying

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25. Concur in general. It is desired to stress the idea that development of Zenith Search radar should not overshadow improvement in long range coverage. If enemy aircraft carry atomic bombs, we can not let them get overhead.

26. Continuation of the effort, already initiated, to standardize units and components, promote interchangeability of electronics spare parts, simplify, etc., is a necessity. However, standardization can be the enemy of progress. Research should be unhindered by standardization. Development and improvement programs can take standardization into account after research has discovered new principles or means of accomplishment.

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needs and limitations of the different size ships and small craft. In addition, two general purpose height finding (fighter director) type radars, one large and one small could be developed using similar components. Similar component parts and circuits and possibly units may well be used in fire control radar equipment. Standardization of electronic equipments and their components is one of the most important improvements required during post-war development.

28. Power Supply. Necessary improvements in radar performance to meet the threats of the future will require that every component be capable of delivering the utmost in performance for its size and weight. Much saving in weight and space may be accomplished for most electronic equipment by a shift to a higher frequency power supply. Because of this fact, a shift of power supply frequency for future mobile radars appears likely from a military standpoint. Many airborne equipments already use 800 cycle power sources. The relative merits of various power supplies have been reviewed by the Board and the following recommendations are made:

a. An orderly change to a higher frequency power supply for certain radars should be instituted in the near future. The optimum frequency should be selected by the Chief of Naval Operations after thorough study and recommendations by the proper material bureaus so that full advantage may be taken of the knowledge, supply and production facilities of commercial interests and other services. The broad difficulties and disadvantages of shifting from 60 cycle supply are well appreciated by this Board.

b. The possibilities of a shift to a higher frequency for power for certain electrical equipment such as synchros and small motors requires investigation and coordination. The frequency should be the same as that used for radar and radio power supplies in order to standardize components.

c. Aircraft and submarines present the most immediate problems because of the increased importance of space and weight considerations. Naval aircraft are using 800 cycle supplies for radio, radar and other purposes. It is understood that Army aircraft and commercial interests are using 400 cycle supplies for various purposes.

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28. The merit of high frequency power supply units has been demonstrated. Space and weight can be saved by using higher frequencies and the associated high speed electric generators. Cincpac concurs with the board's recommendation that further study, investigation, and coordination of efforts in this direction are in order. General agreement on standardization on 400 or 800 cycles between Army, Navy, and commercial interests should be reached so that the cooperation of electrical industrial interests can be enlisted with the expectation of enthusiastic support.

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Standardization of high frequency power supplies of Naval aircraft with the Army Air Forces material seems mandatory to increase the availability of interchangeable spare parts. Conversion of submarines to use of higher frequency power should be given a high priority. The future submarine promises to be a versatile weapon and should be of great value to the fleet as a radar picket and fighter director. In order to build necessary characteristics into a single type submarine, further reduction in size of many equipments will be necessary.

d. Constant liaison with commercial interests in the development of power supplies should be maintained so that full advantage may be taken of their work. It is to our advantage to influence commercial airlines and other mobile services to use a common high frequency power supply. 400 cycles is already being used by many and appears to offer certain advantages over 800 cycles for ship-board use.

29. Weight and Space Consideration. This Board recommends that to reduce the weight and space characteristics of electronic equipment the basic design considerations for electronic equipment be studied for revision as follows: (1) to use miniature tubes and miniature techniques whenever practicable, (2) to withstand reasonable shock and vibration with light-weight external shock mounts for installation where excessive shock or vibration is encountered.

30. Spare Parts.

a. The present practice of furnishing a separate spare parts box for each electronic equipment is unsatisfactory, using up valuable weight and space aboard ship with large stocks of slow moving, low casualty spares. Critical shipping space has been utilized and the re-supply of critical items slowed down by the necessity of packaging a large volume of seldom needed parts together with critical fast moving items.

b. Standardization of component parts, in physical size as well as electrical characteristics, is a necessity. Attempts to standardize electrical characteristics have been made to some extent but the benefits of this standardization have been lost by failure to standardize physical dimensions as well.

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c. Spare parts lists and stocks aboard ship should be based on the bin supply principle and upon requirements of ship types rather than individual equipments. Non-standard items peculiar to individual equipments may continue to be supplied on an equipment spare basis where necessary, if tender or base pool supply will not serve.

d. It is imperative that the distribution of spare parts be such that the spare parts are delivered to the fleet concurrently with the delivery of the new electronic equipment. By this process many items which may prove to be high casualty, critical items will be made readily replaceable from equipment or bin spare parts.

e. A standard stock numbering system for electronic equipment component parts is a necessity. A standard stock catalogue of these items should be furnished to all activities at the earliest possible date.

f. Technically trained supply officers and enlisted supply personnel should administer the procurement, distribution, issue, inventory, and replenishment of electronic spares, under the general administration or with the advice of cognizant electronics trained technical officers. The prohibition upon the use of SKT's (Radio) aboard ship should be abolished.

g. The principle of fleet control of distribution including mainland distribution facilities of electronic equipment and spares to the active fleet should be continued.

31. EFSG and ACG Technicians. This Board recommends that the Airborne Coordinating Group and the Electronics Field Service Group be continued during peacetime and be planned for expansion during war-time. These two groups, by the introduction and standardization of electronics maintenance procedures and in the operation and employment of new electronics system have excellently bridged the large gap that previously existed between the receipt of new systems and effective coordinated employment of these systems in the fleet.

32. The subject of ACG and EFSG technicians is discussed further in the report of the Radio Equipment Board currently convened by CinCPac and is concurred in by this Board.

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33. Standardization of Nomenclature System. The several private nomenclature systems for radar and radio equipments and components used throughout the services today have proven cumbersome and inadequate. The "Joint Army-Navy" nomenclature system is considered the best system now in use. The systems employed individually by the Army, the Navy, and the commercial industries are so incomprehensive in their identification and description of the equipment as to make them of little value to personnel unfamiliar with the particular equipments. Accordingly, considerable confusion has resulted, and will probably continue until a single, descriptive nomenclature system is put into general use in all services and is used in training personnel.

34. This Board recommends that the "Joint Army-Navy" nomenclature system be universally adopted for the designation of electronic equipment; that all equipments in current use be assigned suitable designators; that all new equipments be assigned A-N designators prior to their introduction to service use; and that active Joint use of the A-N system be vigorously encouraged.

35. Publications. It is recommended that many of the various radar technical books, publications and pamphlets, which are now of high classification and with limited distribution, have their classification downgraded and their distribution increased to make such valuable information available to the Fleet Commands as an aid in long range planning of improved electronic equipment installations. Specifically it is recommended that the publications "U.S. Radar Survey, Sections 1 to 7" be distributed to all Fleet Type Commanders. The radar equipment descriptions, operating characteristics and performance capabilities are invaluable reference data for use in connection with material and operational planning purposes. Only CinCPac and ComAirPac are known to have copies at the present time.

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Part II.

Equipments.

Section A.

Surface Search Radar.

Shipborne Surface Search Radar.

1. The following general requirements are considered necessary for any radar to efficiently detect and provide tracking data on surface targets.

a. General. The later model SG radars such as the SG-1b which have incorporated in them such features as sensitivity time control, fast time constant circuits, and expanded sweep are considered adequate for the immediate future. This radar and the later models such as the 8 cm. SG 3/4, it is believed, will have satisfactory performance characteristics for the near future. Development of improved surface search radar should emphasize drastic reductions in size and weight and standardization. Improved range and bearing resolution are desirable.

b. Maintenance. The maintenance of radar equipment must be such that repairs can be accomplished in the minimum time possible. It is believed that this can be accomplished by constructing the equipment on a functional unit basis, with each unit being as light in weight and as small as practicable. These units should be racked in the main frame and be easily removable. Inter-unit connections can be accomplished by the use of pin-jack terminal boards at the rear of each unit. Bench testing facilities, if space permits, would greatly simplify the servicing problem. There should also be a standardization of components with regard to shape and size in order to provide simple maintenance.

1. SG Series.

a. The SG radar was the first surface search equipment made to satisfy fleet requirements. Operational reports soon indicated need for: (1) A more stable receiver, (2) Elimination of sea return, and (3) Better discrimination

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1. a. Although Cincpac concurs with this paragraph, it is desired to note that SG 5/6 types, rather than the SG 4 are scheduled as part of the "modern" allowance in most types of ships. It is considered this allowance will satisfy immediate needs. However, continued research is in order to provide a more effective surface search radar for the future.

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between adjacent targets. The SG-a corrected the fault of receiver instability and this modification was called SG-1 if factory performed. This equipment was highly satisfactory for long range search, but due to excessive sea returns the equipment had to be operated at reduced receiver gain for close search and station keeping. Some ships partially overcame this bad feature by installing "grass cutting" circuits which reduced close range gain by application of a square wave pulse. This was found undesirable since small targets were lost if they were in the outer limit of the range effected by this partial disabling pulse. With the modification of the equipments to SG-b and SG-lb a time varying gain feature was added and permitted close-in search with optimum gain for long range search. In addition to this feature the SG-b and SG-lb satisfied the fleet desire for better target discrimination in range by the introduction of fast time constant circuits in the video amplifier.

b. The past performance of the SG series radars has shown it to be of great value in shore bombardment, torpedo attack, station keeping, detection of low flying aircraft at limited ranges, navigation, and long range surface search. From a material standpoint it has required little repair due to excellent design, ruggedness and serviceability. The fleet, however, still desires better bearing discrimination which could be accomplished through the use of higher frequencies and incorporating an antenna stabilizing unit. It is believed that the SG-4 using higher frequency, spark wheel modulator, and a stabilized antenna will satisfy the fleet needs for an adequate surface search radar for the near future.

c. It is recommended that all SG radars be brought up to the standards of those of the SG-b or SG-lb and that all of the SG-b and SG-lb radars be retained on all ships on the inactive fleet and be replaced by the later model SG series equipments on all ships of the active fleet.

2. SL Series

a. The SL radar was designed as a small ship surface search radar. Within the limits of its design the SL performed in a satisfactory manner. It was rugged, reasonably free from trouble and gave ranges comparable to those of the SG series. Obvious defects in design and

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resulting difficulties in operation make it apparent that the SL series is not adequate for the versatile surface search radar required by small ships. Some of the disadvantages of the SL series are:

(1) All targets are presented on a single seven inch PPI scope and no range scope was included. The moveable range dot and bearing cursor as incorporated in the SL-a and SL-l were an improvement over the etched range circle method used in the SL. However, the range and bearing determination lack sufficient accuracy.

(2) Poor physical construction is evident since the console stands too high and the PPI scope is almost horizontal. This makes constant observation difficult and greatly increases operator fatigue.

(3) The construction of the SL series is not adapted to serviceability. The chassis of the console has all units so arranged as to make servicing difficult.

(4) The antenna control is difficult to operate. Push button control with no provision for manual operation makes it difficult to stop the antenna on a target.

(5) There is no sea return suppressor which makes it difficult to observe close range targets.

(b) It is recommended that all SL series radars be replaced on all ships of the active and inactive fleet by one of the late model SU series radars.

3. SU Series.

a. The SU series radars have given excellent performance in the fleet. The equipment being designed for small and medium ship use (DE's, AM's and PC's) serves its purpose well. It has an angular discrimination of about 4 degrees and a range discrimination of about 300 yards. Its main difficulty seems to be undesirable echos from clouds and mist which cause trouble when using the equipment for navigation and searching in low visibility. The general performance is better than the SL, but its electrical construction is considerably more complicated. At present there is only one antenna speed and it would be desirable to have

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two or three. The SU-1 differs from the SU only in the power supply used and the type of gyro input. Perhaps a lower frequency model similar in design would eliminate undesirable returns from clouds or mist and give the fleet a small, surface search radar comparable to the SG series.

b. It is recommended that one of the late model SU radars be used to replace all model SL radars now installed. It is also recommended that all early model SU radars be replaced by the most recent model SU-2 or SU-3 on all ships of the active and inactive fleet.

4. SO Series.

a. The SO series radars are installed on patrol craft, landing craft, minesweepers, district craft, small auxiliaries and coast guard vessels. This equipment has only PPI presentation which is satisfactory for navigational and station keeping purposes. The SO types are similar in construction, but vary only in antenna weight, power supply, and frequency. The SO-1 has given good results as a surface search radar and has proved valuable for landing craft use at sea and close to shore. It has also been useful for navigation and station keeping. There is a need for an accessory control unit (ACU) and true bearing unit (TBU) modification to all sets should this model be retained. Its resolution and discrimination should be improved. The disadvantages of the SO-1 are its heavy antenna, only fair resolution, and no sea return suppressor. The SO-4 is the successor to the SO-1 and has a higher frequency, but little experience has been had with this equipment. It has, however, shown better discrimination. It would be desirable to have a 3 mile range scale, sea return suppressor, and a more accurate means of obtaining range ("A" scope). The SO-2, 4, 5 and 6 are considered modern since they operate at higher frequencies and are provided with accessory control units. The SO-1 and SO-8 are considered modern, but not the best. It is believed that late model SO series equipments should be retained on ships of the active and inactive fleet where installed except when replacement by late SU series is indicated for specific reasons.

Submarine Surface Search Radar.

1. The following general characteristics are considered necessary for a submarine surface search radar to efficiently locate possible targets:

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a. Range. The maximum ranges should be such that the submarine has the best possible chance of detecting the enemy before the submarine is itself detected, and in sufficient time so that the submarine can be maneuvered to a favorable position to conduct an attack.

b. Bearing. Close bearing resolution is desirable in a surface search radar so that the contact may be properly evaluated. One of the primary missions of the submarine is to furnish contact reports to the O. T. C. Any information obtainable at long ranges will enable the submarine to give more information in the contact report, and as well as plan and carry out an expective attack.

c. Resolution. The range resolution should be in the order of 100 to 150 yards for reasons of long range evaluation of enemy's formation. The best possible bearing resolution is highly desirable for the same reason.

d. Presentation. The presentation offered by a PPI scope and a class "B" scope is considered adequate. An "A" scope is desirable.

e. Frequency. The frequency should be high enough to accomplish the required resolution and be standardized with other types of radars in order to eliminate need for special submarine spare parts.

f. Shock-mounting. Present shock mounting is satisfactory.

g. Maintenance. Maintenance is particularly vital in the submarine as there is only one radar set in the surface search field which will have long range characteristics. Unit replacement with standardized functional units and maximum use of standard components is recommended.

Evaluation of Equipment types now in use for Submarine Surface Search.

1. Model SF Series. This was a good radar within its design limitations and was largely responsible for the successes of the submarines in their numerous and destructive night surface attacks. The early complaints about this model as set forth in submarine patrol reports indicate that its weaknesses were lack of power and the

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lack of PPI presentation. The shortcomings in power were revealed in several instances of lookouts sighting targets ahead of the radar on moonlight nights. PPI presentation was made available for the SJ radar as soon as preliminary tests of surface ship types indicated its great value in convoy attack. After the introduction of the PPI scope an additional complaint appeared in patrol reports as to multiple indications due to the side lobes of the antenna. The SJ remained secure from enemy D/F equipment until late in the war. The increase in the enemy's use of intercept receivers forced the operating personnel into intermittent use of the equipment commencing in the summer of 1944. This intermittent operation appeared to give good security. It is to be noted that this radar was also the fire control radar, so that the officer at the PPI scope acted as a one-man CIC. The SJ radar was replaced in only a few instances by the Model SV radar at the end of the war. In summation the Model SJ radar is now considered obsolete since it has been replaced by two models; one as an air-surface search, and the other as fire control. SJ equipment should remain in the inactive submarines of the reserve fleet. Some time will elapse before 100 percent replacements can be made in the active submarines. For purposes of training submarines in the use of radar the model SJ is adequate. For use against an enemy the more secure three centimeter model SS is better from the fire control standpoint, and the eight centimeter model SV is better as a surface search radar.

2. For Model SV, Series see comments under Air Search II-B-4 (b); For Model SS, Series see comments under Fire Control II-C-6 (c); and For Model ST, Series see comments under Fire Control II-C-6 (b).

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Part II.

Equipment Types.

Section B.

Air Search Radar.

Surface Ship Air Search Radar.

1. The following general characteristics are considered necessary for air search radars to detect aircraft, glide bombs and rockets, and to provide sufficient intercept data for effective countermeasures. (This Board has considered the specifications for the ultimate air search radar as set forth in CNO ltr. (Op-25) serial 00140225A, dated 8 October 1945, to BuShips in formulating the following requirements.)

a. Range. It is considered essential that detection equipment for air targets have at least a range of 300 miles for major combatant ships and a range of at least 150 miles for smaller type ships. The range accuracy should be in the order of 100 yards for purposes of accurate tracking and possible auxiliary use of the radar for fire control. These requirements have not been met by present air target detection equipments, but this has not been too serious a handicap in the past. Due to the predictable increase in speeds of air targets, much greater maximum range capabilities are essential in order that early detection can be accomplished and effective countermeasures taken during the very limited time of target approach.

b. Bearing. The bearing accuracy of air search radar should not be less than one degree in order to permit accurate tracking and rapid coaching of the intercept radar on the air target.

c. Resolution. The resolution in range and bearing should be the best possible consistent with the factors of pulse length, beam width, and peak power. Since very long range air search requires greater energy per pulse, it may be necessary to use greater pulse lengths and so accept a somewhat reduced range resolution at least at the very long ranges. The specifications of the SR-4 are 4 degrees bearing resolution, range resolution of 500 yards, and a horizontal beam width of 8 degrees. This is not adequate for the radar of the future but is not too great an immediate handicap in a radar whose primary mission is detection of air targets. Once a target has been

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1. c. Resolution.

A question is raised here as to the relative merits of SF-3 and SF-4 radars. It is not believed that the fleet has had sufficient experience as yet to make final evaluation between 1200 MC and 600 MC radars used for surface search.

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detected the intercept and fighter director radars must track accurately and they must have excellent resolution. Smaller ships not being able to carry heavy intercept radars should have a single radar capable of a reasonable solution of the intercept problem after detection.

d. Coverage. The coverage of air search radar for major combatant ships should be a right circular space cylinder of 300 mile radius and height of 50 miles. In order to prevent the wide energy distribution in a single beam giving complete coverage it is considered advisable to use an additional Zenith search radar covering position angles from approximately 40 degrees to 90 degrees. This would mean that the air search radar should search and have good coverage from the horizon to 50 degrees position angle. This will be difficult because of the high energy required for such a wide vertical beam. Coverage might be accomplished more readily if the antenna beam were made small in the vertical direction and "nodded" through the limits desired.

e. Frequency. The carrier output frequency of air search radars should be above 400 MC in order to prevent interference with the proposed UHF communications channels. Other reasons for higher frequency are: smaller size of antenna, narrow beam widths, reduction in equipment sizes, and increased ability to pick up small targets. Present low frequency equipments have caused interference in communications channels, have had wide beam widths, and heavy antenna structures. It is believed that the SR-4 equipments with a frequency range of 525-615 MC may prove to be more satisfactory than existing equipments. However, it is recognized that it may be impossible to satisfy long range requirements except by the use of lower frequencies. Accelerated development and service tests of radically improved air search radar prototypes are considered essential.

f. Antenna. The air search radar antenna must be light in weight, rugged, constructed for simple replacement of parts and easily maintainable. Some ships may require stabilized installations. Present air search antennas have given the fleet many troubles such as pedestal failures and corrosion of dipoles which were not replaceable without removing the entire antenna. The present antennas are of light weight metal but should be made more rugged. The use of higher frequencies may aid greatly in correcting many present antenna difficulties.

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g. Shock Mounting. The shock mounting of air search radar equipments should be improved if possible without excessive increases in weight. Some of the air search radar equipments now in use have been unsatisfactory in this respect.

h. Maintenance. The maintenance of radar equipment must be such that repairs can be accomplished in the minimum time possible. It is believed that this can be accomplished by constructing the equipment on a functional unit basis, with each unit being as light in weight and as small as practicable. Standard components should be used throughout. (See Section L on Standardization.)

i. Presentation. The presentation must be such that evaluation of the air problem can be made rapidly and efficiently. It is believed the present methods in present equipments using an "A" scope for range and a PPI scope for the overall air picture are reasonably satisfactory. Associated projection type PPI's would be of great value, and it is believed that new photographic schemes giving a large size reproduction of the master PPI will be satisfactory. Improved presentation with characteristics similar to optic presentation or with look through features is very desirable.

j. Moving Target Indication. It is considered essential that all air search radars be provided with a moving target indicator system or some improved type system that will facilitate tracking of aircraft over land masses.

k. Standardization of Range Scales. The selection of standard range scales for various search radars and PPI scopes is a controversial problem which has received a great deal of attention by operational units and by technical designers. So many opposing factors are involved that no completely satisfactory solution has been achieved as yet and arbitrary decisions have been required. The present standard PPI scales of 4, 10, 20, 80 and 200 miles have been reasonably satisfactory for remote PPI's. They do not appear satisfactory for Air Search radar consoles. For air search and intercept work there is need for 10, 30, 100 and 300 mile scales. With increased performance and future developments this need will increase. The 20, 80, and 200 mile scales are too long or too short for most uses.

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It is recommended that the question of standard range scales be restudied and approached from the combined standpoint of tactical requirements and radar wave propagation limitations.

Experience has shown that 19 to 24 miles is a critical range at which low flying aircraft are first detected, hence the need for a 30 mile scale. 60 to 90 miles have also proved critical ranges on medium altitude aircraft, hence the need for a 100 mile scale. As radar performance improves on high flying aircraft there will be an increasing need for a range scale longer than 200 miles.

In surface search radars it appears that the 10 mile scale is most used and considered most important. A shorter scale is needed for close work and station keeping which has resulted in variously recommended scales of $1\frac{1}{2}$, 3, 4, 5, 6 and 8 miles. If a scale greater than 10 miles is required, 30 miles seems best. Maximum ranges on large surface targets vary from 45,000 to 60,000 yards. A 100 mile scale would sometimes be useful in navigation and detection of aircraft.

This Board recommends:

- (a) Standard scales for air search radars of 10, 30, 100 and 300 miles.
- (b) Standard scales for surface search radars of 3, 10, 30 and 100 miles.
- (c) Standard ranges for PFI scopes of 3, 10, 30, 100 and 300 miles.

1. Standardization. All major units should be standardized in order to facilitate rapid maintenance. This has been accomplished in the SR series radars in which the PFI section of the SR is also the VE remote which can be used to replace the PFI unit of the SR. In a like manner, if the SG-3 or SG-6 is used in conjunction with the SR, the receivers, IFF coordinator units, training control units, monitor scopes, and range scopes are interchangeable in either of the sets. There should also be a standardization of components with regard to shape and size in order to provide for simple maintenance.

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1. k. Standardization of range scales.

Cinccpac concurs. However, it is believed that a gradual and logical change commensurate with funds available can be accepted. It appears that the 3, 10, 30, 100, 300 mile range combinations are desirable in future construction. The problem is worthy of continued study and periodical review in the light of changing tactical concepts.

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2. Evaluation Of Equipment Types Now In Use For Air Search.

SA Series.

a. The SA radar has proven entirely inadequate as an air search radar. Its 30 degree horizontal beam and 50 degree vertical beam give a very low gain and a poor power directivity. Excessive fade zones were encountered which resulted in detection at 50 miles under best conditions, target fading at 40 miles, and failure to detect target again until the range had closed to about 20 miles. The SA-1 differed slightly in that its beam pattern was 40 degrees horizontal and 60 degrees vertical. It is recommended that all SA series radars be replaced on all ships of the active and inactive fleet. Specifications of SR series radars show that various models are being produced to satisfy weight and space requirements for various ship types. The SR series should be used for immediate replacements.

SC Series.

b. The SC is considered obsolete and requires no comment. The SC-1 which was designed to replace the SC had the additional feature of PPI scope. The performance of the SC-1 as an air search radar was fair, giving maximum reliable ranges of 80 miles on medium altitude aircraft. The poor beam pattern gave poor bearing accuracy, and excessive side lobes caused ambiguity of targets at ranges less than 20 miles. The SC-1 also had a bearing sector scan which proved to be neither successful nor desirable. It is believed that higher speed scanning would result in better overall coverage and presentation. The later SC equipments were basically the same as the SC-1 but differing in antenna design and various slight circuit modifications. The bad features of the SC series are: poor beam pattern, excessive fade zones, poor choice of range scales inconsistent with the capabilities of the equipment, poor design from the maintenance standpoint, inability to track targets over land, insufficient shock mounting, limited range capabilities, inability to determine altitude accurately, and a poorly designed antenna pedestal. It is recommended that the SC series radars be replaced by late model SR series equipments as soon as practicable on all ships of the active and inactive fleet.

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2. This section of the report is considered an excellent presentation of merits, advantages, disadvantages, limitations, etc., of different types of air search radar with which the fleet has had experience.

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SK Series.

c. The SK radar series are the same as the SC-2 and later SC series with the exception of the much larger antenna. The SK antenna horizontal and vertical beam width of 20 degrees gives greater power gain and somewhat better resolution. The SK-2 and SK-3 models used a parabolic dish antenna instead of the mattress type. The SK-3 antenna had an additional parasitic array giving better coverage on high flying planes at less than 50 miles range. In general the faults of the SK series consoles and power supplies are the same as the SC series since the equipment is basically the same. The SK-2 antenna suppressed side lobe radiation, but the parabolic reflector and the point radiation source widened the fade zones and reduced high angle coverage. It is recommended that all SK series radars be replaced by late model SR series radars with improved antenna designs on all ships of the active fleet.

SR Series.

d. The SR radar was the first attempt to standardize air search radars and to provide a frequency distribution in various models. The SR series is considered a big step in the right direction. A reliable and complete evaluation of the SR series equipment is difficult since they have been in the fleet for only a short time and not enough information is available for accurate service evaluation of some of the equipment characteristics. Upon the installation of the first SR equipments in the fleet, two glaring defects were immediately apparent. These are: difficult transmitter tuning procedures and the short life the type 527 A oscillator tubes. Both defects were apparently caused by the keyer unit which allowed the selection of two pulse rates and pulse lengths. Practically all reports indicate trouble with tuning and short oscillator tube life, the overall effect being a high percentage of maintenance hours and low operating efficiency. The low detection ranges reported were probably caused by faulty tuning. The SR radar without factory modifications or field changes is definitely inferior to both the SC and SK series radars in detection capabilities and operational efficiency. With the installation of the new keyer (providing plate keying and a single pulse length of four micro-seconds) the transmitter tuning was simplified and the life of the 527 A oscillator tubes was extended to a period comparable to the type 327 A's used in the

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SC-SK series radars. Although there were other field changes to the SR, this modification was of sufficient value to give a new designation of the equipment as SR-a. Most fleet units and activities contacted expressed a desire for a 20 micro-second pulse in addition to the 4 micro-second pulse incorporated in the SR-a on the theory that this greater pulse length would give approximately 1.5 times the original range (assuming constant peak power). However, it is understood that Westinghouse has made exhaustive tests with the two pulse lengths and concluded that little or no extension of range with the greater pulse length was accomplished. Other considerations, such as shorter tube life caused by greater average power consumption, also made the inclusion of the long pulse length impracticable. It is recommended that a single pulse length be retained in the SR-a equipment. The change of range scale from 400 to 200 miles on the "A" scope was desirable since the equipment only had a maximum range of a little over 100 miles on air targets at medium altitudes.

e. Available reports concerning the SR-a are very encouraging. Although some activities queried were reluctant to commit themselves with a flat statement, others are emphatic in their opinion that the operation of the SR-a equipment is equal to, and in most cases superior to, the SK in many respects. Enough reports stress the ability of the SR-a to give good high angle coverage to indicate that the SR-a antenna has some definite advantages in that respect over the SC/SK. Although there are no fade charts available for comparison, operators are of the opinion that the fade areas are about the same in number as those of the SC/SK but that they are of smaller extent. This seems reasonable in view of the different antenna design and increased power of the SR.

f. The antenna design of the SR allows the radiation pattern to approach more ideal characteristics than those of the SK. For most complete coverage and for best detection and medium range tracking of aircraft, the antenna radiation pattern should be narrow in the horizontal plane and wide in the vertical plane. This desirable trend in antenna construction made its appearance with the SC-1 radar and reports from the fleet proved its superiority for high angle coverage over that of the CXAM and the SC.

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g. As compared to the SC-2/3 antenna the SR antenna design tends toward the narrow horizontal and wide vertical beam pattern, the main lobe being 20 degrees in the horizontal and 55 degrees in the vertical plane. Good high angle coverage is the major advantage resulting from the change. Further development along these lines is of great importance and should be carried forward until antenna patterns of 4 degrees or less in the horizontal and 60 to 70 degrees in the vertical plane become practical.

Maintenance Comparisons.

h. The SR-a or the SR is definitely superior to the SC/SK from the maintenance view point. The mechanical construction of the equipment is excellent with adequate test points at accessible places for completely checking all important circuits rapidly. Automatic overload relays, open fuse indicators, panel tuning of antenna tank and duplexer circuits, receiver tuning at either the transmitter or console are but a few of the refinements which make the maintenance and adjustment of the SR-5 easier and more rapid than that of the SC/SK series equipment. As noted previously, the tuning of the transmitter was of such a nature as to offset all other advantages of the SR but the SR-a eliminates this difficulty almost entirely. It is natural to expect that until maintenance personnel can become thoroughly familiar with the SR-a, some difficulties can be expected with adjustment and maintenance. Similar trouble was experienced with the SC series of equipments when they first made their appearance in the fleet. Another important maintenance feature of the SR is the unit standardization incorporated in the construction.

i. The SR-5 equipment is the SR-a equipment with the keyer unit located again in the main transceiver frame. This has the advantage over the SR-a in that all essential parts are located in the same frame rather than having the keyer unit in a separate frame. The SR-5 also has an improved synchro control unit. Otherwise, the equipment appears unchanged and the performance of the SR-a and SR-5 are expected to prove identical.

Operators Comparisons.

j. About the only source of information on the operators angle was that supplied by the Radar Operators School and some meagre information from the action

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reports of the various ships. Most operators, particularly those with experience on the SC/SK, desire the large 12 inch PPI scope supplied with the SC/SK rather than the 7 inch vertical tube of the SR. Possibly this desire is coupled with the habits of operating the larger scope and the familiarity accompanying it. Operators just starting on both equipments seem to find the SR arrangement as good or better. The size of the console scope is not considered important for the 7 inch presentation of the SR will show up equally as well as that of the 12 inch tube. However, the location of the controls does merit some consideration. With the SR, all controls are placed in a fashion which makes it necessary for the operator to raise his arms, sometimes to shoulder height, in order to operate them, while the SC/SK, they are at a low level and are less fatiguing to operate. Further, with the SC/SK, the operator, has only to raise his eyes to observe the "A" scope while with the SR, he must lean to the right to obtain target composition and accurate range. However, this appears to be offset by the advantage gained by the standard unit. The height of the equipment is awkward unless a special chair or stool is provided. This is a minor consideration to be accounted for upon installation and has no bearing on the merits of the equipment itself.

k. The IFF presentation is a definite advantage, for the separate base line for IFF purposes does not permit interference in the IFF system to be applied to the "A" scope. This is important where large concentrations of radars are operating and where IFF interference is heavy.

l. The bearing indication allows quicker observation with the SR direct reading dial than that of reading the "bug" against the bearing ring of the SC/SK. Since most of the bearings are taken directly from the PPI however, this is not a major advantage.

m. Dissatisfaction has been expressed in practically all cases with the antenna speeds provided with the SR equipment. At present they stand at either 1 1/2 or 5 RPM, the one being too slow for good Fighter Direction work and the other being too fast for this equipment. Most ships have remedied this with unauthorized modification in the field to allow operation of from 2 to 4 RPM and a standard field change is scheduled for a variable rate from 1 to 5 RPM which will eliminate this difficulty.

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Conclusions.

n. As previously stated, until such a time as a large volume of reports on the operation of the SR becomes available, a final evaluation of the SR equipment should not be made. However, several points are reasonably clear and lead to the following conclusions:

o. The present SR (unmodified) is not adequate or satisfactory in its present form to replace either the SC or SK series radars. Short tube life, difficulty of adjustment and the accompanying short detection ranges make it undesirable.

p. The SR-a is superior to the SR and the field change to modify the SR to the SR-a should be provided at the earliest possible date to all ships having SR installations. Preferable to this is the replacement of the SR with the SR-5 or higher frequency models of this series equipment as they become available.

q. Comparative Trial data are required on 200 mc., SR-a radars and those of the new SR series air search radars using higher frequencies, above 400 mc.

Submarine Air Search Radar.

3. The following general characteristics are considered necessary for a submarine radar to efficiently detect air targets and to provide sufficient information for the submarine to take effective countermeasures.

a. Range. The maximum range capabilities should be such that the submarine will have sufficient time to take defensive countermeasures before the aircraft can locate the submarine. Present ranges of submarine air search radar have been from 15 - 18 miles which is not satisfactory and must be extended particularly if the submarine is to be used as an early warning radar picket.

b. Bearing. The Bearing accuracy should be sufficient for the submarine to give accurate early warning data to other forces.

c. Resolution. The Resolution in range and bearing should be sufficient for the submarine to evaluate an air attack and to provide accurate early warning data to other forces before taking necessary countermeasures.

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d. Position Angle. The determination of position angle is necessary if the submarine is to be used as an effective fighter direction vessel.

e. Presentation. The presentation method should stress identification of friend or foe since the submarine is very vulnerable to air attack. It should give a complete picture of air targets overhead as well as those approaching.

f. Antenna. The submarine antenna should be as small as possible to prevent visual detection. For this reason it is believed that periscope-mounted wave guide antennas are the most desirable. Since such an antenna inherently has a wide lobe, bearing accuracy may require the use of high frequencies and some form of lobe switching.

g. Zenith Search. The submarine air search radar should be capable of giving complete vertical coverage. The determination of position angle is desirable in that it gives the submarine a better picture of the tactical situation, but this is not considered essential since the patrol submarine is largely interested in the presence and general direction of an air target rather than its altitude. A wide vertical lobe antenna pattern in conjunction with PPI presentation should give indication of a target in the vertical sector by producing a circle on the PPI scope when the antenna is rotated.

h. Automatic Tracking. This feature is not considered necessary for the air search submarine radar.

i. Frequency. Because of the small antenna required the carrier output frequency should be as high as possible without suffering excessive interference from atmospheric conditions.

j. Shock Mounting. The shock mounting as now provided in the SV radars is considered satisfactory.

k. Maintenance. The Maintenance requirements are the same as those set forth in Part II-B-1(h).

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4. Evaluation of Equipment Types now in Use for Submarine Air Search.

SD Series.

a. The performance of the SD series for submarine use has not been very good. The disadvantages are: Insecurity from enemy interception, inability to detect low flying aircraft, and lack of bearing information. Since the submarine is not by choice an anti-aircraft vessel it was sufficient in the early phases of the war merely to know that a plane was present, regardless of where it was. The weakness of insecurity from enemy intercept became so great that various forms of intermittent use were dictated. Patrol reports have shown that this radar was seldom used because of this bad feature. A replacement program is at present underway to replace the Model SD series on active submarines and should be carried out.

SV Series.

b. This radar, being the first combination surface and air search radar for submarine use, has given excellent performance and has given ranges from 10 to 15 miles on aircraft. Exceptional ranges on surface craft have been recorded and these are:

Large Surface ship	60,000 yards.
Small Surface ship	45,000 yards.
Submarine Surfaced	35,000 yards.

This radar will serve the needs of the present and near future, but the radar of the foreseeable future should have a radically greater range and complete coverage particularly if the submarine is to be used as an early warning picket. It is recommended that this radar be retained on all active submarines, installed on new construction, and steps taken to improve its coverage and range on air targets.

5. Zenith Search Radar. The following general characteristics are considered necessary for a Zenith search radar to efficiently search the overhead sector and to provide sufficient data for effective countermeasures to be taken:

a. Coverage. The Zenith search radar should cover a conical volume of space through position angles of 40 degrees to 90 degrees with a maximum slant range of not less than 30 miles.

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5. Zenith Search.

It is desired to note that development of Zenith Search radar should not have higher priority than efforts to provide the best possible long range coverage. Atomic bomb considerations emphasize this point.

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b. Presentation. The presentation should be such that bearing, position angle and range are conveniently displayed.

6. Methods Used for Zenith Search:

a. SG radar with Zenith search reflectors.
This scheme necessitated the removal of the standard reflector and replacing it with a special reflector to give Zenith coverage. This obviously compromised the use of the SG radar as a surface search radar and was not very convenient to use. Such a scheme is not considered satisfactory and has not proven satisfactory where tried.

b. SCR 720B. This method employed an airborne radar using a spiral scan covering the overhead sector from position angles of 50 degrees to 90 degrees. This method is considered a more logical approach to the problem since it only requires the addition of a light equipment specially suited for the purpose. The SCR 720B is no longer used but it served its purpose as an interim measure. The design of an equipment to be used specifically for this purpose is considered essential and all ships of the active fleet should be equipped with such a radar as soon as practicable.

7. Ship-Borne Control of Interception Radar.
The following general characteristics are considered necessary for any radar to provide sufficient data for control of interception against attack by aircraft, glide bomb, or rocket.

a. Range. The maximum range capabilities should be comparable to the range capabilities of the air search radar in order that interception data may be provided immediately after detection of the air target. Present intercept radars have given average ranges of about 60 miles, which was sufficient during the recent war. However, the predictable increase in target speeds makes it mandatory that the range be radically extended. The range accuracy should be high enough to provide accurate tracking data. It is believed that plus or minus 200 yards range accuracy will satisfy this requirement.

b. Bearing. Since interception must be made at much greater ranges in the future, the bearing accuracy must be improved. The bearing accuracy of the SP radar is about plus or minus .5 degree using the eight foot reflector.

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6. An entirely satisfactory Zenith Search radar has not been furnished to the fleet as yet.

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This has been satisfactory since interception was made at relatively close range. However, if interception is made at 250 miles, an error of .5 degree means a lateral error of approximately 2 miles. Bearing accuracy of .25 degrees or less should be the goal in future intercept radar equipments.

c. Position Angle. The position angle accuracy should be as high as possible. The SP radar at present has a position angle accuracy of about plus or minus five mils. In terms of altitude this is plus or minus 1000 feet at 30 miles or 8000 feet at 240 miles. This is not considered satisfactory for future use. Since position angle and range are used to determine altitude, the position angle accuracy should be in the order of 1 or 2 mils.

d. Resolution. Resolution is an important requirement for the interception problem at long ranges and should be improved in view of great target speeds to be expected in the future.

e. Presentation. The method of presentation must be such that all data necessary to carry out the interception is conveniently displayed. Present equipments giving range, bearing, and altitude data are considered satisfactory insofar as the method of presentation is concerned. Development of simulated optical presentation schemes and "look thru" features may be valuable.

f. Acquisition. The problem of target acquisition assumes importance whenever a "pencil" beam radiation pattern exists. Since this is of necessity the type of beam used in an intercept radar, some means other than rocking the antenna should be provided to improve acquisition. It has been suggested that a nodding dipole or nodding waveguide feed should be provided for the purpose of vertical acquisition. Due to the excessive weight of the SP/SM antenna it is not considered practical to provide automatic antenna nodding such as is used in the Mark 28 Mod. 2/4 TACU system. Spiral scanning and variable beam width should be considered.

8. Evaluation of equipments now in use for control of interception.

a. SM Radar. The SM radar was the first shipborne equipment designed for the control of fighter direction. Its excessive weight (18,000 lbs.) limited its installation to large aircraft carriers. It was used for low

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8. interception.

Evaluation of equipment now in use for control of

experience. An excellent analysis which is the result of fleet

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angle search and gave good ranges on low flying aircraft and surface ships. Since the performance of the SM has been the same as that for the SP, the much lighter version (9,000 lbs.), the difficulties and recommendations will be discussed under the SP radar.

b. SP Radar. The SP radar is the lighter weight version of the SM which permitted its installation on small carriers, battleships, cruisers and even special destroyers. The performance of the SP has been good, with ranges of about 60 miles on medium height aircraft and reasonably accurate altitude data. This radar has partially satisfied fleet needs for the past and will probably have to be used for the present and immediate future. Operational reports have indicated the following difficulties to be existent:

- (1) D.C. step by step gyros caused antenna to hunt during small course changes.
- (2) The Mark 8 Mod. 3 stable element has been troublesome because it apparently lacks sufficient gain to operate follow up circuits without hunting.
- (3) The extreme complexity of adjustment of the stabilizing system as a whole has proven to be beyond the capabilities of most radio technicians.
- (4) The range unit calibration has proven to be too complex for rapid adjustment by the operator.
- (5) Communication, and bearing failures and excessive end play in various motor generators have been the cause of many failures.
- (6) Amplidyne failures have been numerous either due to the amplidyne being underrated or influenced by proximity to high power radio frequency fields.
- (7) Altitude determination has often been erratic because of the errors of the stabilizing system.

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- (8) The "B" modulator has proven to be useless because of poor design.
- (9) The entire system is so complicated that average fleet technicians have been unable to cope with it. Partial satisfactory operation was obtained largely through the efforts of factory engineers.

The following suggestions and recommendations for improvement of the SP have been compiled from fleet reports and from personnel at the Electronics Maintenance School, Oahu, T. H.

- (1) Improved antenna control system necessitating redesign of the follow up system and a lighter antenna.
- (2) Improved 600 cycle motor generator set used with the "A" modulator.
- (3) Improved anti-hunt feedback system in the Mark 8 Mod. 3 stable element.
- (4) Modify equipment so that three modes of operation are possible. These should be true-stabilized, true-unstabilized, and relative-unstabilized. This is deemed necessary in event of failure of the stable element.
- (5) Latitude correction synchros should always correct for earth rotation independent of relative-true operation.
- (6) Provide means of disengaging bearing handwheel when slewing motor is used. The unbalance of the handwheel causes a periodic varying search speed of the antenna.
- (7) Make "B" modulator operative or remove it.
- (8) Make calibration of range unit simple enough for operator to accomplish.

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- (9) Provide stabilizing signal amplifier with electronic feedback circuit which can be suitably adjusted to allow operation of the follow up circuits without causing hunting.

It is recommended that SP/SM radars be retained in all ships of the active and inactive fleet until such time as the SX or a better intercept equipment becomes available.

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Part II.

Equipment Types.

Section C.

Fire Control Radar.

1. Surface Fire Control Radar. The following general characteristics are considered necessary for any radar to efficiently control Naval Gunfire against surface and shore targets.

a. Range. The maximum range capabilities should be such that a solution of the tracking problem can be obtained prior to the time the range has closed to a value consistent with the maximum effective range of the gun battery. In general, the fleet has found that the range capabilities of the latest types of surface fire control radars have fulfilled this requirement. The range accuracy of the latest types of equipment has been satisfactory and commensurate with the range accuracy of the associated gun battery.

b. Bearing. The bearing accuracy should be such that accurate tracking can be accomplished at maximum range and must be commensurate with the inherent deflection dispersion of the gun battery. This requirement has not been met by most of the present fire control radars. Recent specifications have required bearing accuracy within plus or minus one to three mils. Maximum possible bearing accuracy is required for full radar control firing.

c. Resolution. The range resolution should be of the order of magnitude of 100 yards in order to permit tracking of targets close to land masses and to permit effective fire on targets having approximately the same bearing and differing slightly in range, and to permit accurate spotting. Bearing resolution should be such that two targets having a range difference less than the range resolution of the equipment and a bearing difference of one and one half degrees or more can be clearly identified as separate targets.

d. Spotting. Accurate spotting by radar is an essential requirement. All surface fire control radars should be provided with the best possible means of radar spotting, both in range and azimuth. In order to accomplish

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this it is considered necessary to design all surface fire control antennae to permit horizontal beam scanning. The fleet has found that electrical beam scanning has been operationally satisfactory, but due to the complexity of the system it has not been practicable to service it adequately. The horizontal "rocking horse" antenna has also been operationally satisfactory and is more easily maintained. However it is recommended that experiments be conducted to determine the feasibility of incorporating the nutating wave guide principle in horizontal scan antennae in order to further simplify the scanning mechanism.

e. Presentation. The radar presentation should be as similar to optical presentation as possible. The B type presentation is admirably suited for this purpose and is also the best method known for spotting. The fleet has found that equipments using the type B presentation have been more useful than those using other methods such as "pip" matching and "wonder spot".

f. Automatic Tracking. Automatic tracking features are considered very desirable. These features should be: automatic ranging, automatic bearing follow up, manual or "lock in" control, automatic feed of range and bearing rates directly to the computer, computer aid circuits to permit continuous tracking during momentary target fades, and provisions for automatic display of target course and speed, own ship course and speed and other pertinent data to remote stations such as CIC, flag plot, bridge etc. A device similar to the attack plotter as used in the anti submarine warfare problem should be considered in developing a method of displaying the data obtained.

g. Frequency. The carrier output frequency of the surface fire control radar should be as high as practicable without suffering excessive interference from atmospheric disturbances. The fleet has experienced some difficulty in the "X" band due to "trapping", phantom targets, and reduced ranges in misty or foggy weather but is highly satisfied with the higher resolution, greater accuracy, and lighter equipments obtained by the use of these higher frequencies.

h. Shock Mounting. Little difficulty has been encountered in late model equipments, such as Mark 13, as a result of insufficient shock mounting. It is believed that continued normal developments along this line will correct any minor faults now existent.

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1. Maintenance. The maintenance of radar equipment must be such that repairs can be accomplished in the minimum time possible. It is believed that this can be accomplished by constructing the equipment on a functional unit basis with each unit being as light in weight and as small as practicable. These units should be racked in the main frame and be easily removable. Inter-unit connection may be accomplished by the use of pin-jack terminal boards at the rear of each unit. Partial examples of this type of construction are found in most equipments, but the program should be carried out more fully. If space conditions permit, it would be of advantage to have bench testing facilities which would permit servicing of the faulty unit at leisure after the rapid repair was accomplished by replacing the faulty unit with a spare. It is believed that necessary reductions in weight and size can be accomplished, as is in the case of many aircraft radars, by the use of miniature tubes and components and higher frequency power sources.

2. Evaluation of single and double purpose Equipment Types now in use for Surface Fire Control:

a. Mark 3: This was the first fire control radar equipment used and is rapidly being replaced by more modern types. It operated in the 700 mc. band. This equipment had many limitations which made it unacceptable for an efficient fire control radar. These limitations were: inability to obtain accurate bearings; inability to give acceptable range and bearing discrimination; inadequate protection against shock and vibration within the equipment itself; limited spotting capabilities. As an interim equipment in fire control radar development this radar served a very useful purpose. It is now obsolete and should be replaced on all ships in the active and reserve fleet.

b. Mark 4: Since this equipment, although a double purpose radar, is the same as the Mark 3, with the exception of its antenna and position angle scopes, the same comments as mentioned above for the Mark 3 apply when this equipment is used for surface fire control. This equipment is discussed in subsequent paragraphs on anti-aircraft radar.

c. Mark 8 Series: The Mark 8 Mod 0 main battery fire control radar was developed to eliminate the shortcomings of the Mark 3 type radar. It was the first equipment to employ a rapid linear horizontal scanning beam using a "polyrod" antenna. This type of scan in conjunction with the "S" band frequency made use of type "B" presentation which permitted spotting. The frequency used permitted a narrower beam and its resultant increase in bearing

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accuracy. The chief disadvantages were extreme mechanical and electrical complexity of the system as a whole and the excessive weight which limited its use to major combatant ships. The Mark 8 Mod 1 improved the maximum range obtainable by use of a redesigned transmitter and receiver having respectively greater power output and greater sensitivity. The Mark 8 Mod 2 was developed in response to fleet requirements that the range operation be removed from the director to the main battery plotting room. The Mark 8 Mod 3 development resulted in the following advantages: reduction in antenna weight of nearly 2000 pounds; an electrically and mechanically simplified antenna; a greater maximum range; better spotting capabilities resulting from the inherently better bearing accuracy and resolution and the better range resolution all resulting from the higher "X" frequency band used. It is recommended that all Mark 8 radars be replaced by the Mark 13 (see paragraph (e) below) in all ships of the active postwar fleet. If there are insufficient Mark 13 equipments now on hand or in production to supply the ships of the inactive reserve fleet it is recommended that the Mark 8 be retained in ships of the inactive reserve having same until such time as new equipments fully meeting the requirements of the fleet can be produced. All of the Mark 8 equipments retained should be brought up to the standards of the Mark 8 Mod 3.

d. Mark 12 Series: The Mark 12 Mod 0 was developed as a replacement model for the Mark 4 radar. This equipment has shown marked improvement in reliability, serviceability, range capabilities, side lobe suppression, and tracking accuracy. Its automatic tracking in range and the computer aid circuit are a partial answer to the fleet needs for complete automatic tracking features. Fleet reports have indicated that the spot presentation is a superior method for tracking in train and elevation, but circuit complexity make proper adjustment difficult. These reports also indicate that the Mark 12 is superior to the Mark 4 and has given very satisfactory results with the exception of having limited spotting facilities, and insufficient range and bearing resolution. The Mark 12 Mod 1 is identical to the Mark 12 Mod 0 except that the range unit was removed from the director to the radar transmitter room. In addition to the limitations mentioned for the Mark 12 Mod 0, the Mark 12 Mod 1 is limited by the manual range step control in the director permitting only a 300 yard per revolution change in range, and by the "coasting" of the range step when using the slewing control. The test unit incorporated in

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in the transmitter has proved valuable, but it is difficult to keep in proper operation. When modifications are made to permit better control of the range step by the range operation in the director, it is recommended that Mark 12 Mod 0 be converted to Mark 12 Mod 1 on all ships of the active and reserve fleet. It is further recommended that the Mark 12 Mod 1 be retained as dual purpose fire control equipment until such time that a completely new radar system is developed which will satisfy the minimum conditions for the fleet needs set forth in sections II-C-1 and II-C-3.

e. Mark 13 Series: The experience gained through the limited use of this equipment has shown that of all equipments now on hand it most nearly meets the requirements of the fleet as stated in section II-C-1. It has performed well operationally, providing excellent spotting, a high degree of range and bearing resolution, and good maximum range. The system is designed for the unit replacement method of repair to a greater degree than in previous types. However, there is still need for improvement in design in this respect. The equipment fails to provide automatic tracking features as discussed in paragraph (C, 1, f). It is recommended that Mark 13 equipment be installed on all new construction battleships and cruisers. It is further recommended that Mark 13 equipment be used to replace all Mark 8 series radar installed on ships of the active postwar fleet, and on as many ships of the inactive reserve fleet as is possible with the equipments now produced or in production.

f. Mark 26 Series: This equipment was designed for use on Destroyer Escorts and auxiliaries and is limited to giving range data only. It is used with the Mark 52 director and originally served the purpose for which it was designed. However, if the ships on which the Mark 26 radar is installed are used for picket duty, as was done near the termination of the war, it should be replaced by a more versatile radar. Its performance within its designed limitations has been considered very satisfactory and it is recommended that it be retained for the use for which it was designed.

g. Mark 28 Series: The Mark 28 equipment was originally designed for automatic weapon control on large ships but was adapted for use with the obsolescent Mark 33 director for secondary battery control on some large ships and for main battery control on some destroyers as an emergency measure. Its performance in the above connection was inadequate. Fleet reports have shown that this inadequacy was caused by the following: circuit complexity of the

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system as a whole, insufficient range capabilities to permit tracking beyond the range of the gun battery involved, inadequate spotting facilities and lack of automatic tracking features. The advantages of the Mark 28 Mod 0/3 are: light weight, small space requirements, adaptability to unit replacement, reasonably good range and bearing resolution, and minimum side and back lobe radiation. It is recommended that the Mark 28 series be classified obsolete for main and secondary battery fire control and be replaced by the Mark 34 Mod 2, 3, 4, or some superior equipment on all ships of the active and inactive fleet. If changes in director systems permit the installation of heavier equipments it is recommended that the Mark 12 (or Mark 13 if weight and space considerations permit) be installed. The Mark 28 equipment may prove useful as a general purpose fire control radar for small ships and auxiliaries because of its light weight and reasonable performance, and should be retained for such use where required. It is also considered useful as a gunnery officers information radar and should be retained as such in large ships until something better is available. The Mark 28 Mod 2 and 4 was later used with Mark 63 automatic weapons control system and is discussed under Mark 28 in a later paragraph under AA fire control radar.

3. Anti-Aircraft Fire Control Radar:-

The following general characteristics are considered necessary for any radar to efficiently control naval gunfire against aircraft, glide bombs, and rockets:

a. Range:- The maximum range capabilities should be such that a solution can always be obtained prior to the time the range has closed to the maximum effective range of the gun battery. In general, the fleet has found that the range capabilities of the latest types of anti-aircraft fire control radars have barely fulfilled this requirement for present 5" - 38 cal. batteries. It is believed that with the advent of faster aircraft, guided missiles, and rockets, the maximum range of both radars and guns must be radically extended. Development of a greatly improved long range A.A. fire control radar is therefore mandatory. The range accuracy of the recent type equipments has been satisfactory and consistent with the accuracy of the associated gun battery. (i.e. fuse times etc.).

b. Bearing:- The bearing accuracy should be such that accurate tracking can be accomplished at maximum range and such that gun-laying accuracy will be the equivalent of that given by optical methods. The permissible error should not be greater than 1 mil and should be as

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much less as possible. The recent types of anti-aircraft fire control radars have shown reasonably good bearing accuracy. However, with the increased speed of aerial targets, improvements must also be made in this respect. At present, the primary difficulty experienced by the fleet can be traced to the "human" error resulting from presentation methods (see Presentation) rather than from the inherent error of the radar system itself. The Mark 25 radar (now under contract) is understood to have a bearing accuracy of 1 mil.

c. Position Angle:- The accuracy of determining position angle should be the same as that specified above for bearing. Here again it is not so much the lack of accuracy of the equipment, but the lack of accuracy resulting from the "human" error, caused by the method of presentation, that is not acceptable. Position angle should be determined to an accuracy of plus or minus one mil for position angles from one degree to eighty-five degrees. The only equipments which have approached this requirement are the Mark 22 and Mark 34 which have been able to determine position angles as low as two degrees above the horizon. The Mark 25 radar is understood to be able to determine position angles to an accuracy of one mil.

d. Resolution:- The range resolution should be about 100 yards or better in order that the "averaging" effect of multiple targets in the same general area, causing the radar to select the average point as the point of aim, will not be sufficient to permit the targets to lie outside the lethal radius of the projectile burst. The bearing and position angle resolution must also be sufficient to eliminate the effects of "averaging" in these components. It is believed that 0.65 degree beam widths may satisfy this requirement and it is understood that this will be the beam width of the Mark 25 radar.

e. Moving Target Indicator:- It is considered essential that all anti-aircraft fire control radars be provided with a moving target indicator system in order to permit tracking of aircraft making approaches over land masses.

f. Target Acquisition:- All anti-aircraft fire control radars must be provided with a rapid and efficient means of target acquisition in order to permit tracking as soon after detection as possible. Provision should be made for manual or automatic locking of the scan axis on the target after the target has been found by the

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3. b. c. d. AA Fire Control Radar.

Again it appears necessary to comment that Mark 25 Radar, although undoubtedly superior to those with which the fleet as a whole is familiar, should not be considered the ultimate in design. Continued effort towards improvement is desired. It is understood that the Mark 35 Radar integral in the Gun Director Mark 56 will provide a much superior system.

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acquisition beam. "TACU", such as used in the Mark 28 Mod 2/4 and the Mark 34 Mod. 2, has proven to be reasonably satisfactory, although there has been limited experience with this equipment. It is recommended that experiments be conducted to determine the feasibility of using nutating wave guide scan for target acquisition purposes. Another possibility for improving target acquisition systems may be the use of variable beam width radiation patterns.

g. Spotting:- Accurate spotting by radar is considered an essential requirement for the accurate control of long range and medium range gunfire against an aerial target. All AA battery fire control radars should be provided with the best possible means of radar spotting in range, deflection, and elevation. In order to accomplish this, two possibilities become apparent. These are: the use of two antennas, one for vertical scan and the other for horizontal scan utilizing class "C" presentation (azimuth versus elevation) for the purpose of elevation spotting and class "B" presentation (range versus azimuth) for the purpose of range and deflection spotting, or the use of a single antenna employing a spiral scan and utilizing class "D" presentation (azimuth versus elevation) for the purpose of deflection and elevation spotting and an "A" presentation for range spotting. However, for dual purpose gun fire control it is believed that the first method is more desirable. Descriptions of the Mark 25 radar which have been received by this Board indicate that this equipment may be adaptable to the requirements set forth in this section.

h. Presentation:- The radar presentation should be as similar to the optical presentation as possible. The class "B" and class "C" methods are admirably suited for this purpose and are also the best known methods for effective spotting. It is also believed that an "A" scope should be provided for the range operator.

i. Automatic Tracking:- Automatic tracking features are essential for all anti-aircraft radars and associated guns. These features should be: automatic ranging, automatic bearing and elevation follow up, manual or lock-in control, automatic feed of range and bearing rates direct to the computer, computer aid circuits to permit continuous tracking during momentary target fades, and provision for automatic display of target course, speed, dive or climb angle, altitude, and other pertinent data to remote stations. The range, bearing and elevation rates (made available by automatic tracking) used in conjunction with

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target present position data could well be used to provide an optical presentation of the overall air attack picture by using this information to control a moving light spot projected on a large plotting board.

j. Remarks on Frequency, Shock, Mounting and Maintenance: are the same as set forth in paragraphs (g), (h), and (i) in Part II - C - 1.

4. The Evaluation of Equipment Types Now in Use for Anti-Aircraft Fire Control.

a. Mark 4;- The same remarks as set forth in paragraph II-C-2b apply with the following additional comments: This equipment has proved unable to obtain accurate position angle data at position angles below twelve degrees and is therefore inadequate for use against aircraft attack at low position angles. The Mark IV radar equipment is now considered obsolete and should be replaced on all ships of the active and inactive fleets.

b. Mark 12 Series:- The same remarks as set forth in II-C-2d apply to this series when used for AA fire control. In addition, difficulty has been experienced in obtaining accurate position angles on low flying aircraft. This difficulty was alleviated by the use of the Mark 22 in conjunction with the Mark 12 series. The fleet has found that this combination of radars is reasonably satisfactory within the limitations of the Mark 22 (See Mark 22). It is recommended that the Mark 12 Mod. 1 - Mark 22 combination be retained on all ships of the active and inactive fleet as a dual purpose fire control system until such time as a new equipment is developed which will satisfy the basic requirements for the fleet set forth in paragraph II-C-3 above.

c. Mark 22 Series:- The Mark 22 Mod. 0 radar equipment was designed for use with radar equipments Mark 4 and Mark 12 to provide low angle tracking of aircraft. This radar has proved very valuable when in proper operation. However, lack of sufficient operational and maintenance training and the circuit complexity of the system have caused the fleet serious difficulty in maintaining the equipment in operation. These difficulties have resulted from the following:-

(1) The Klystron local oscillator, whose frequency stability is highly sensitive to temperature

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changes, is located in the transmitter unit on top of the director in a very exposed position. If practicable the transmitter unit should be relocated within the director or in a compartment as near the director as possible.

(2) The Mark 22 Mod. 0 provides only elevation information which is presented on a "collapsed" "C" scope giving elevation information only at the pointer's location in the director. It is understood that in addition the Mark 22 Mod. 1 will provide the more desirable feature of full "C" presentation at the range operator's position.

(3) This equipment is not sufficiently shock mounted for ship board use. As a result, tuning difficulties are experienced, especially in connection with the automatic frequency control features.

(4) Accidental movement of external controls on the main frame occurs as a result of crowded conditions in the director. It is considered desirable that these controls be recessed into the front panel.

(5) Since the Mark 22 is "keyed" by the Mark 12, power supply breakdowns to the Mark 12 permit the Mark 22 magnetron to cool and be damaged if the Mark 12 resumes operation before the Mark 22 is placed in the "standby" condition. This could be remedied by a modification to the Mark 22 causing the magnetron cathode heater to be automatically cut on when the tube starts to cool. Since the Mark 22 radar equipment has aided materially in fighting efficiency and since the above difficulties could be remedied without major changes in the system, it is recommended that the Mark 22 Mod. 1 equipment be retained for use in conjunction with the Mark 12 Mod. 1 on all ships of the active and inactive fleets as a dual purpose fire control system until such time as new equipment meeting all the basic requirements for the fleet set forth in paragraph II-C-3a is produced.

d. Mark 28 Series:- The Mark 28 series radar equipment has been only partially satisfactory as a dual purpose radar system with the Mark 33 director, but has been reasonably satisfactory as a heavy machine gun fire control radar with the Mark 63 director.

The Mark 28 Mod. 0/3 equipment, as used with Mark 33 directors for dual purpose control, showed the

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following difficulties in addition to those listed in paragraph II-C-2g: serious difficulty in locating air targets and poor position angle determination on low flying aircraft at position angles of 6 degrees or less. The Mark 28 Mod. 2/4 equipments had the additional feature of a target acquisition unit which aided greatly in locating air targets and permitted these equipments to be used with the Mark 63 director system. It is recommended that the Mark 28 Mod 0/3 be classified obsolete but that it be retained with Mark 33 directors only until such time as the Mark 33 director system is replaced by a satisfactory director system. It is further recommended that the Mark 28 Mods. 2, 4, used in conjunction with the Mark 63 director system, be replaced by Mark 34 Mod. 2, 4 on ships of the active fleet, but retained on ships of the inactive fleet until such time as an equipment is produced which will meet the basic requirements of the fleet as set forth in II-C-3a. The Mark 28 radar has been used to advantage as a gunnery officer's information radar in large ships and should be retained as such until something better is available. The Mark 28 may also be useful for installation on auxiliary types of ships as a general purpose fire control radar. Many such ships that will remain in active service have no adequate fire control radar.

e. Mark 34 Series:- There appear to be very marked advantages to the use of 3 centimeter radar systems as compared with 10 centimeter systems for blind firing control of AA automatic and heavy machine guns on all types of ships. The Mark 34 series radars are composite equipments using 3 centimeter transmitters and antennas. The present status of the various Mods. is understood to be as follows:

- Mod. 1 - Never produced.
- Mod. 2 - Uses ST transmitter and Mark 28 Mod 2 below deck components.
- Mod. 3 - Uses Mark 19 below deck components.
- Mod. 4 - Uses Mark 28 below deck components.

Little actual battle experience has been reported for the Mark 34 series because it is a recent installation. However, operational training exercises have indicated that this is an excellent radar with worthwhile advantages over earlier systems. The fleet desires that this type of equipment be capable of full automatic tracking in all future design and planning. In the interests of standardi-

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zation it is recommended that the Mark 34 Mod. 3 be classified obsolete and that the Mark 34 Mods. 2/4 be used to replace the Mark 28 Mods. 2/4 in Mark 63 and Mark director systems on all ships of the active fleet. Consideration should be given to similar replacement on ships of the inactive reserve.

f. Mark 25 Series:- This radar, now under contract, will probably satisfy many of the present requirements for an efficient anti-aircraft fire control radar. It is a combined 1.25 and 3 centimeter automatic tracking system with an overall weight of 4000 lbs. The performance to be expected and the specifications of design are listed in "Radar Survey" Section II page 2 - 69,70,71. If the Mark 25 radar meets specifications it should be installed in all appropriate units of the active fleet.

5. Submarine Fire Control Radar. The following general characteristics are considered necessary for a submarine fire control radar to control efficiently torpedo, gun, and rocket fire.

a. Range. The range capabilities of submarine fire control radar should be such that a solution of the torpedo or gunfire problem can be reached before the target should be fired upon. In the case of torpedo attack part of the approach phase may take place on the surface. This will require a maximum range of radar equipment of about forty to fifty thousand yards on large combatant vessels to permit the necessary surface run to gain position for attack. The range accuracy of the latest type radars has been satisfactory. Should the technique of submarine detection by radar improve, the maximum range should be increased to give a region in which the submarine can operate on the surface undetected.

b. Bearing. The bearing accuracy should be improved as much as possible as the state of the art progresses. The bearing accuracy of the Model SS-1 radar is satisfactory for torpedo fire. If it is intended to keep gun armament on submarines, radars with bearing accuracy similar to the fire control radars on surface ships should be employed, and the submarine equipped to use radar control of gunfire.

c. Resolution. The range resolution should be in the order of 100 yards or less to permit the tracking of a target close to the shoreline and for spotting

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4. f. Mark 25 Series.

The latest information available is to the effect that three centimeters only will be employed in the radar Mark 25. The Gun Director Mark 56 with associated radar Mark 35 and built-in computer may prove to be such a superior system that curtailment of the radar Mark 25 development program will result. It is understood that both of these systems are under intensive study at present and operating tests of the radar Mark 35 in Gun Director Mark 56 are scheduled for the near future. However, radar Mark 25 appears to be the ultimate radar for the gun director Mark 37 system.

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gulfire. Bearing resolution which will distinguish ten thousand ton merchant ships which are 1000 yards apart at a range of 40,000 yards is desired. It should be practicable to evaluate a contact on a group of ships at that range in order that the O.T.C. may be adequately informed of enemy composition, course, speed, and formation before the submarine dives to attack.

d. Spotting. Accurate spotting by radar is an essential requirement. The low height of eye on a submarine makes optical spotting erratic. The latest radars permits spotting in range only. Improvement in beam width for deflection spotting is needed.

e. Presentation. The radar presentation should be as similar to the optical presentation as possible. The PPI scope and "B" scope now furnished is suitable for attack on surface targets. It is apparently not the present intention to use submarines as anti-aircraft vessels. Should this become necessary some other form of presentation should be provided to include the third dimension similar to that required for surface ships AA radars.

f. Automatic Tracking. Automatic tracking features are very desirable for submarine fire control. The solution to the torpedo problem, because of complicated zig-zag plans which will be used by the enemy, will require a computing tracking mechanism with every possible feature for predicting the enemy's course and speed during the torpedo run. An integrated fire control system is now under development and is known as Computer Mark 31. One trial installation, using some of the latest features, is installed in the U.S.S. SEALEOPARD, and there are many faults in that system. Automatic tracking features should be improved for submarines to include every possible aid to the solution of the problem.

g. Frequency. Because of the resulting improved beam shape, a high frequency is desirable. It is believed that no special frequency is needed for submarines unless an extremely short wave antenna is designed for submerged work at night. The present periscope radar does not resolve sufficiently in bearing to permit its use at times when a bearing cannot be obtained optically. Submarines have used their radars for inter-communication with some success. Having all submarine radars in the same general band would facilitate this but would increase interference among radars and vulnerability to enemy jamming. Several

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comments have been heard suggesting that submarines use radar to talk to friendly escort types. These questions are further discussed under the IFF section. It is recommended that submarine radars use the optimum frequency band required to obtain desired (radar) performance and that no particular effort be made to have different ships use widely different frequencies. Communication among submarines and surface craft can be more efficiently handled in other ways.

h. Shock Mounting. Present shock mounting for submarine radars is satisfactory.

i. Maintenance. The maintenance problem must be considered as a part of the standardization program. Small, lightweight functional components with plug-in connections appear to be the best answer to the problem of maintenance. Standardization will result in less time spent in training personnel to service various radars. Because of the small spaces and in some cases the unusual geometric shapes of available spaces in submarines, neat stacks of equipment are not possible, but if components are of the plug-in type repair will be an easier matter.

6. Evaluation of equipment types now in use for submarine fire control.

a. SJ Series:- The SJ series radars served their purpose well for torpedo fire control, but the method of presentation (A and PPI scopes) and poor bearing accuracy do not make it particularly suited for an all-purpose fire control radar such as the SS radar. (See additional comment under Submarine Surface Search Radar). The SJ series radars are considered obsolete and should be replaced in all submarines by the SV - SS combination. However, the training program will not be made less effective by its continued use until it is replaced.

b. ST Series:- This radar was an immediate success from the electronic standpoint but, being a periscope radar, required a slightly larger head on the periscope. This feature compromises visual detection, but this is offset by the rapidity of observation giving all necessary information on the target in 3 or 4 seconds. Since the SS radar will be installed, it is recommended that the ST radar be retained for training purposes until such time as the model SS is installed.

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c. SS Series:- This equipment has not been used on patrol during the war but tests have proven it to be ideal for the submarine fire control problem. It has a range resolution of 75 yards, a bearing resolution of 1 degree, range accuracy of 15 yards plus one percent of the range, and bearing accuracy of .25 degree. The type of presentation, being either class A or B, makes it useful for gun control and spotting as well as for torpedo control. It is recommended that the SS radar be used to replace the SJ and ST radars on active submarines as soon as practicable.

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Part II

Section G

Airborne Early Warning Equipment

1. AEW as a system, has not been used operationally except in tests at CIC GTC Brigantine and on the USS RANGER, in both cases using pre-production or experimental equipment.

2. The installation in the USS BUNKER HILL is the first complete shipboard installation and was only recently given its first operational test. An installation was made in the USS HORNET but as yet it is untried.

3. There are several recommendations to be made regarding the maintenance of the AEW gear on board ship. A separate maintenance shop should be provided; it is impracticable to service AEW in the usual shop installations, because of size and weight. Also, a test bench set-up seems particularly necessary even at the expense of removing some other installation.

4. In view of the fact that the equipment is new, and it is not known which components will give trouble, there should be a stock of spares within a reasonable distance of the operating area of the carriers. At least 200% spares should be carried until service tests prove which items are most needed and the inventory of the spares can be changed accordingly.

5. At present AEW receivers are not being furnished to ships other than the parent ships. Consideration should be given to placing equipment in other types such as Fleet and Force flags, pickets and submarines.

6. The present form of AEW radar is considered to be of limited and problematical future value unless it can be redesigned to detect targets over land masses and eliminate sea return. The need for an airborne radar picket radar is discussed under Part II, Section A of this report.

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It is recommended that AEW equipment already developed be given a thorough trial in the fleet. It has definite desirable characteristics. In view of the complexity of the AEW arrangement involving air operations, plane-to-ship relay of radar signals and difficulties of interpretation of the pattern presented on shipboard as relayed from a fast moving radar, many problems are presented which must be worked out at some length. Improvements are needed in the equipment and the development of effective operating procedures must be completed before the full value of this equipment can be realized. Attention is invited to the previous comment on paragraph 17, page I - 7, regarding the potential value of this equipment for the exercise of command in the air.

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Part II.

Section J.

IFF Equipment.

1. Despite the important and useful service rendered by the Mark III IFF system, reports from the Fleet indicate that this system is considered to be generally unsatisfactory. Faults reported were, in general, as follows:

a. Unreliability. Except for submarines, which have had fair to good results with the present system, reports indicate that the best results have been obtained by larger units of the fleet. This is believed to be a result of the fact that larger fleet units generally have a greater number of technicians qualified to service IFF equipment. It is felt that a system which requires constant expert servicing to produce reliable performance, and which does not have the full confidence of the fleet, will be of very limited usefulness. It is therefore felt that every effort must be made to insure the maximum of reliability, simplicity, standardization, and facility of servicing (including accessibility and the provision of carefully prepared instruction books).

b. Inability to discriminate between targets. This is caused by insufficient discrimination in range, bearing, and elevation. The most important manifestation of this fault has been the loss of enemy targets as they approach friendly targets. As a result of the non-directional characteristics of some IFF antennas, and of back and side lobe radiations from directional IFF antennas, enemy targets were often confused with friendlies when they approached the same range as friendly targets, even though the bearing of the friendly and enemy targets might be as far apart as 180 degrees. Other difficulty was encountered when variations in the pulse length of IFF signals caused variations in range discrimination. War-time experience has indicated the necessity for providing IFF equipment with range, bearing and elevation discriminations equal to that of the radar with which it works. This is considered to be of great importance for IFF equipment designed to operate with fire-control radars.

c. Antenna size. As a result in the great increase in the numbers of electronics equipment installed in Naval vessels and of the consequent increase in the number of antennas, serious interference has developed between the antennas of different electronics equipment resulting in serious distortions of electronics antenna

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radiation patterns, often causing blank spots in radiation patterns on some bearings. In order to reduce to a minimum the interference of IFF antennas with the radiation patterns of other equipment, it is imperative that IFF antennas be made as small as possible consistent with the required range, bearing, and elevation discrimination characteristics. In order to accomplish this it is recommended that the use of higher frequencies for IFF, be exploited to the fullest extent.

d. Lack of security. Reports of enemy use of IFF equipment having signals similar to our Mark III system at times caused considerable perturbation in the Fleet. The security of our IFF system is of great importance. In order to maintain such security, some system of coded challenges and responses is required. This system should provide for the continued use of equipment, and for security, even after the basic equipment has been compromised. In order to provide additional security, it is felt that provision must be made for the identification of ships and aircraft by means of local triggering of coded radar signals or of coded IFF signals in addition to provisions for distant triggering of IFF transponders by friendly IFF transmitter-responders. For identification without interrogating and triggering of distant transmitter-responders, the use of coded modulations superimposed on own radar pulses to be identified by friendly RCM intercepts is considered to be a necessary development.

e. Inability to discriminate between different groups of friendly targets. In many cases where different codes of the Mark III system were used in an attempt to provide for identification of different groups of friendly craft much loss of time and inaccuracy occurred, as a result of the necessity for very close examination and lengthy thought processes on the part of operators. The type of presentation of IFF signals on present indicators makes it extremely difficult to discriminate between different IFF code responses, particularly at long ranges. It is felt that in the improved IFF, codes used should provide for the identification of at least twelve different groups of air and/or surface craft simultaneously, and should provide facilities for varying the code used within each group at least twelve times within twenty-four hours without requiring the return of aircraft to carriers or shore bases for the accomplishment of such

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changes. A definite need exists for two types of IFF indicators. One type should differentiate only between friend and foe and should light a red light or ring a bell (or both) when a target is interrogated and fails to give a friendly response. The utilization of indicators which show friendly and enemy units in different colors should be valuable on PPI scopes as part of this purpose. The other type of IFF indicator should differentiate not only between friend and foe, but also between different types or groups of friendly craft. The type of indication used for both purposes should be completely automatic and should not require either careful examination or lengthy thought processes on the part of the operators. The second type may take longer and have much more restricted presentation than the first.

f. Difficulty of keeping IFF equipment set on proper frequencies. In the present state of the art, IFF systems which operate on a spot frequency are undesirable in view of the probable difficulties in lining up all equipments on the same frequency and keeping them so aligned. A reasonably broad transmitter and receiver are desirable to improve reliability of responses.

g. Lack of IFF equipment on fire-control radar. The inability to discriminate between friendly and enemy targets on the screen of fire-control radars has been keenly felt. This was especially true in the case of friendly and enemy planes in close proximity. While jury-rig IFF equipment, and lately Mark 32 fire-control IFF, have been mounted on some gun directors, and a moderate degree of successful operation was obtained therefrom for both main and anti-aircraft batteries, the utility of these installations was severely limited by the short-comings of the basic Mark III IFF equipment, as discussed above. It is considered essential that each fire-control radar be equipped with IFF capable of rapid identification of its own target. The perfection and installation of satisfactory IFF equipment on all fire-control radars on active Fleet vessels should be given a high priority.

h. Lack of IFF facilities in radar counter-measures equipment. The inability of radar counter-measures operators to discriminate between signals of friendly and enemy craft at times caused considerable confusion. It is recommended that serious study be made

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as to the desirability of incorporating IFF features in radar countermeasures equipment. The value, to a submarine for example, of being able to positively identify friendly radars without making any interrogating transmission is obvious.

i. Lack of standardization. The failure to use standardized components, standardized cabinet and mounting facilities, standardized power supplies, and standardized output impedances caused many unnecessary difficulties. As an example: In an attempt to attain directivity of A-band IFF, BO antennas were used with EN interrogators. This resulted in an increase of directivity, but caused fairly considerable decreases in maximum range because of mismatch. If more than one system of IFF is developed, it should be designed to be used in the same cabinet, or at least to be installed in the same space, and to operate with the same power supplies and connections, so that installations in the Fleet can be varied in as short a time and with as little work as possible during war-time. Any new IFF system developed should be standard for Army, Navy, Marine Corps and Air Forces.

2. This Board does not concur in the opinion expressed in paragraph 4(e) of CNO letter serial 00140225A of 15 October 1945 to the effect that IFF development should proceed separately from radar development and that an IFF system should not be included in detection radars until the characteristics of new IFF systems are known. It is realized that Mark V and Mark VI IFF systems, although improvements over the Mark III system, still leave much to be desired. It is felt that a new series of approaches to and studies of the IFF problem are required along lines indicated herein. It is felt that IFF must be developed hand-in-hand with new search and fire-control radar systems, and with radar countermeasures equipment. Furthermore, regardless of the progress of IFF studies and developments, it is felt that provisions for IFF should be included in each search and fire-control radar and countermeasures system in order to insure that the Fleet can be prepared in minimum time to conduct offensive operations utilizing the latest types of equipment actually available. Against an alert and modern equipped enemy, an adequate IFF will be a most vital part of every radar system.

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2. It is felt that some unwarranted apprehension is indicated here on the part of the board. Cincpac does not interpret Paragraph 4(e) of CNO letter serial 00140225A of 8 October, 1945, to preclude the proper coordination of radar IFF and RCM development. It is recommended that all possible means of electronic identification be investigated with a view to early development of a satisfactory IFF system to replace the Mark III. A reserve system should also be provided.

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Part II.

Equipment Types.

Section K

Countermeasures (RCM)

General Comments.

1. Research and development to improve countermeasures methods and equipment should be vigorously carried out. Our present equipment should be redesigned, unified as to racks or cabinets and power supplies, simplified and made more flexible. Improved directional intercept receivers are required. Better radar jamming and radar deception equipment is needed. Better means of diverting or nullifying electronically guided or controlled missiles are needed. It is considered that RCM activities should be a part of, or controlled by CIC. Our ships and aircraft should make continued and determined efforts to intercept strange electromagnetic wave radiations in all parts of the world. Knowledge of what other nations are doing is vital in this field.

2. ELECTRONIC DECEPTIVE DEVICES.

a. Electronic deceptive devices have not played a major role in the Pacific Theatre. The deceptive device which was available for use against the Japanese was Moonshine, AN/APQ-15. The inadequacy of the Japanese radar made the use of this deceptive device not worth while

b. As radar and operating techniques improve throughout the world, it probably will be necessary to have various electronics deceptive devices developed for use against air search and fire control radars. In spite of the cost of research and the lack of evidence of the value of these devices to date, it is recommended that the Navy continue development of present devices and experimentation with new ideas. Production should be limited to those needed for test and training purposes.

3. NON-ELECTRONIC DECEPTIVE DEVICES.

a. These devices, in general, consist of Window, Balloon-supported decoys, and corner reflectors of various types. Such devices were not only used in an

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attempt to deceive the enemy, but also for training our radar operators and making radar targets of life rafts, for search parties, and of target rafts for radar-controlled gun practices.

b. Such devices have been used by our aircraft, surface vessels, and submarines with good results and have proved to be valuable weapons. They are lightweight, rugged, and easy to use.

c. It is recommended that experimentation with non-electronic deceptive devices, both propelled and non-propelled, be continued. Production should be limited to those required for test and training purposes. Small stocks of any specially useful device developed might be useful in an emergency.

4. CONTROLLED DEVICES COUNTERMEASURES (ROCCM).

a. ROCCM has not been used in the Pacific because the Japanese did not employ radio operated controlled missiles, proximity fuzes, and similar devices against our forces as did the Germans.

b. Several DE's in the Pacific were equipped with intercept, analysis, and jamming guided missiles countermeasures equipment for use in the event that the Japanese used such missiles against us.

c. Radio operated controlled missiles employed in a next war probably will not use the same frequency range as did the ones of the recent war, but the necessity for combating such devices will be ever increasing.

d. The same recommendation is made for ROCCM as was made for COMCM in that section.

5. COMMUNICATION COUNTERMEASURES (COMCM).

a. COMCM has been used very little by the Fleet in the Pacific War. Attempts have been made on several occasions to jam enemy radio communications by CW interference using standard shipboard radio transmitters. The UL (XCE) type modulators for standard shipboard transmitters have not been used in jamming operations to date as far as is known.

b. It is recommended that the development of COMCM and ROCCM equipment be carried on simultaneously

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with a view to using the same or similar equipment for both purposes. It is believed that ROCCM should be given the higher priority in view of the probability of the greater use of radio operated controlled missiles, proximity fuzes, and similar devices. However, COMCM should not be overlooked and may prove very important in the future.

6. INTERFERENCE WITH VT FUZES.

a. The introduction of VT projectile fuzes opened another excellent possibility for the use of countermeasures by the enemy. There is no knowledge of the enemy's use of jamming for the purpose of causing premature detonation of VT projectiles, but there is evidence that during the operation for the capture of Okinawa, VT projectiles were detonated early, presumably by interference from our own radars. Signals from the SP, SCR 584 and other S band radars might conceivably trigger the fuze if the projectiles path crossed the radar beam. This aspect of jamming merits consideration and investigation both from the standpoint of adequate protection from enemy countermeasures and the development of devices for use against enemy projectiles of a similar nature.

7. POST-WAR EMPLOYMENT OF RADAR COUNTERMEASURES.

It is recommended that the every-day employment of RADCM be prosecuted with vigor. With this in mind, the following recommendations and comments are offered:

a. The training of radar technical and non-technical personnel in schools should continue as it is presently carried on. All commissioned personnel should become familiar with RADCM, its capabilities and limitations.

b. Training afloat might be as follows: Fleet training exercises could be participated in by all ships and aircraft equipped with RADCM equipment. Exercises would include the interception of our own radar signals (or of strange signals produced to simulate enemy radars) determining the bearing, and finally the electronic jamming of such radars or simulated radars. Operators of these victim radars would then attempt to minimize the effects of such jamming by means of the various AJ techniques. Coordination of RADCM and CIC must be stressed in order to obtain the maximum benefit from such fleet training exercises.

c. In order to familiarize operating personnel with the radars of other countries of the world,

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intercept receivers and direction finders in our ships and aircraft should be used while in the vicinity of foreign countries and in their ports, for reasons given earlier in this report. To aid personnel in identifying the signals of our own radars, the information concerning their characteristics should be promulgated to all ships and aircraft as necessary. Sufficient and accurate information concerning our own radars was not available to all ships of the fleet until late in the war.

d. One of the greatest lessons of the war in the Pacific was the realization of the necessity for adequate intership communications for RADCM control. Should RADCM assume greater importance, it might be necessary to assign a separate communication channel for its control. It is felt, however, that existing radio channels, as employed during the war, will suffice. Training in radar intercept reporting and control of jamming must be conducted in order to familiarize our personnel with RADCM terminology. In order to maintain the proper security of our own radar frequencies, our training and policies, line of sight UHF voice channels in lieu of HF or VHF channels should be employed in these training exercises.

e. The countermeasures organization on board ships should be a part of the CIC organization although the actual RCM equipment need not, and usually should not, be in CIC. All information obtained by RCM intercepts should be delivered to CIC and evaluated by the RCM Control Officer without delay. Instant action and decision on intercepts of enemy radar is usually of great importance. Delays in handling intercept information cannot be tolerated. CIC should control both intercept and countermeasure subject to the policies and decisions of the embarked Flag Officer, if there be one and the Captain of the ship. Flag Officer and Captain must be kept informed on RCM matters and make basic decisions.

8. RADCM INTERIOR COMMUNICATIONS.

a. Interior communications between RADCM and CIC has consisted mainly of the use of sound powered telephones. This RADCM circuit often has been shared with the radar operators' circuit or others, which has often resulted in confusion.

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b. Good interior communications are essential between the two stations since both must work together in order to obtain the best results from each. It is recommended that there be a separate sound powered telephone circuit between these two stations on all types of ships in order to obtain good interior communications. If a particular ship desires to have RADCM on a sound powered circuit with other stations, they then can parallel the circuits as desired. It is advisable that RADCM be one of the stations on one of the ship's MC systems in order to provide a secondary (or it might become a primary) means of interior communications.

INTERCEPT EQUIPMENT.

9. General.

a. It is recommended that the various pieces of equipment comprising the radar intercept receiving and direction finding system be integrated into one rack or cabinet. Since the receiver must always be accompanied by its associated equipment, the pulse analyzer and panoramic adaptor, it seems logical that the complete equipment should be considered as a unit. There should be free access to component parts for ease of repair and maintenance. Such a design would eliminate the troublesome patch cords now used and would decrease the size and weight of RADCM installations.

b. It is recommended that adequate test equipment be provided each ship equipped with radar countermeasures equipment. Such equipment is essential for the proper and continued calibration of receivers and jammers and for the periodic lining up of the receiver and panoramic adaptor.

c. Careful consideration should be given to the redesign of all RADCM equipment. Much more sensitive and selective equipment is required, capable of receiving any enemy frequency and taking accurate bearings on pulsed signals up to the upper frequency limit of our own radars. Present equipment is inadequate in many respects: (1) lack of selectivity, (2) inability to take accurate direction finder bearings, and (3) difficulty of maintenance.

d. A detailed study of antenna design and location is required to determine the best antenna gain possible, taking into consideration practical limitations

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on size and weight and the requirement for all-round coverage, utilizing a minimum number of antennas. Some ships now require at least two antennas of each receiving type to obtain 360 degree coverage. Direction finding antennas have often been blanked out in some sectors, due to poor choice of locations.

10. AN/SPR-1

a. The AN/SPR-1 radar intercept receiver has operated with very few electrical or mechanical failures and has stood up well under long periods of service. However, it is not a satisfactory piece of equipment for the future. The selectivity is poor and image and harmonic responses to strong signals are prevalent. The large number of responses caused by the ship's own radars and those of nearby ships exasperates many an operator and reduces the efficiency of the intercept watch. Wave Traps have been designed and inserted in the antenna input line. Although they have been of assistance in determining whether a signal was true or false, they leave much to be desired in actual performance. It is possible that each wave trap might be geared by means of cams to its corresponding tuning unit and that a simple switch might be employed to cut the wave trap in or out of the antenna input line.

b. It is recommended that, for shipboard installation, the receiver and accompanying pulse analyzer, panoramic adaptor, and wave traps be integrated into one cabinet in such a way as to provide free access to component parts for ease of repair and maintenance. At the present time, connecting coaxial cables are at the front of the equipment and are liable to damage by striking and bending. It is also recommended that, if practicable, the tuning units to be employed with an intercept receiver, be incorporated in the equipment, changing from one frequency band to another to be accomplished by means of a simple but reliable switching arrangement.

c. Intercept receivers must be designed and perfected soon which will receive signals up to the highest frequencies of our own radars or of any which we might encounter in war with any power. Such equipment should be used during peace time in our ships and aircraft while in the vicinity of other countries and in foreign ports, to aid in the determination of the trends in the field of

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radar by other nations and to provide training for our own operators.

d. It is recommended that a most careful and detailed study of the design of antennas to be used with this equipment continue, with a view to obtaining the very best antenna gain consistent with practicable size, weight, ruggedness, and complexity. Great consideration must be given to the placement of antennas aboard ships and aircraft to obtain 360 degree coverage with a minimum number of antennas.

e. Test equipment should be provided to line up and to calibrate the intercept receiver and associated equipment. Experience has shown the need for signal generators to calibrate properly the plug-in tuning units. Such calibrations must be repeated at various intervals, especially after replacing defective vacuum tubes.

11. RDO.

a. The RDO radar intercept receiver designed to replace the AN/SPR-1 was delivered to the Fleet during the latter stages of the war. Not many units of this type were used in combat operations. The meagre experience gained from the use of the RDO indicates that, although the receiver is capable of detecting the desired transmissions, its lack of selectivity makes it quite difficult to identify properly intercepted signals. It proved troublesome in this respect to even the most experienced operators. The comments on the selectivity of the AN/SPR-1 apply equally well to the RDO. An intercept receiver is desired which is sufficiently selective to make possible immediate and positive discrimination of intercepted signals. The motor-driven plug-in units which are supplied with the RDO are a helpful addition to the manually tuned units. However, ships do not always have 28 volts dc available for the tuning motor. It has been found that the speed at which the units are tuned through their range is too fast and that after constant usage, the motors become quite noisy. The driving motor situation should be reviewed with a view toward elimination of all noise whether in audio or radio frequency bands.

b. Previous remarks on placing all units in a single stack or cabinet, and on the necessity for study and redesign of antennas, all apply to the RDO as well as the AN/SPR-1.

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12.

AN/APR-5AX.

a. The AN/APR-5AX radar intercept receiver was designed and procured on a crash basis to provide the fleet with a receiver whose frequency range was above that of the AN/SPR-1 to detect enemy radars suspected to be in that range. It is not a satisfactory piece of equipment for the future nor for training purposes. Operation of the receiver is far too complicated. Due to the lack of any preselection, our own S-band radars clutter the receiver with a myriad of responses. This equipment is not suitable for the needs of the fleet.

b. It is suggested that it may be practicable to provide a blanking pulse to be applied to similar intercept receivers which will shut off the receiver for the period during which the ship's own radars of S-band or higher frequency are transmitting.

c. The APR-5AX possesses a broader band pass than the RDO and, in operating technique, requires that a signal be intercepted in at least two positions of the tuning dial in order to make identification possible. It is well understood that the development of a satisfactory search receiver covering frequencies above 1000 mcs has confronted laboratories with many difficult problems. However, until a sufficiently selective receiver with sharp band pass to make possible immediate and positive identification of intercepted signals is developed, search receivers covering the range between 1000 and 6000 should be considered as only stop-gap equipments.

13.

SPR-2.

a. The SPR-2 radar intercept receiver was to replace the AN/APR-5AX. Reports indicate that performance is little, if any, better than that of the AN/APR-5AX. However, relatively few units have been used in the Pacific and it is possible that the equipment has not been given a fair trial.

b. It is recommended that development of intercept receivers for ranges above 1000 mcs continue, with special emphasis on improvement of selectivity and simplicity of operation.

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PULSE ANALYZERS.

14. AN/SPA-1 (AN/APA-6A).

a. The AN/SPA-1 pulse analyzer has given satisfactory performance under all battle conditions. While not capable of producing absolutely accurate measurements of PRF's and pulse widths, nevertheless results were usually good enough to permit radar identification by experienced operators. The great difficulty was experienced when two or more radar signals were passed by the companion receiver, the AN/SPR-1 or the RDO. This criticism applies to the selectivity of the receiver and not to the materiel performance of the pulse analyzer. This AN/SPA-1 measures PRF's with an accuracy that is seldom better than 15% unless the set is constantly calibrated, which cannot be done when the equipment is in constant use. It is considered that this equipment is obsolescent and, as such, should be replaced whenever an analyzer capable of accurately measuring PRF's by means of a built-in audio oscillator is available. At present an audio oscillator should be part of RADCM installation if an SPA-1 is installed.

b. It has already been recommended in the SPR-1 section that the analyzer be integrated into one cabinet with the intercept receiver and panoramic adaptor.

15. RDJ.

a. The chief advantage of the RDJ pulse analyzer is the inclusion of a built-in audio oscillator for providing a more nearly accurate measurement of the PRF of the intercepted radar signals.

b. Comment on the success of the RDJ and its operation at sea is very limited due to arrival and installation of only a very small number of such units this far in the Pacific Fleet. It is considered that the use of a 5" scope instead of the 3" scope in the older AN/SPA-1 is an improvement worthy of mention in addition to the built in audio oscillator.

PANORAMIC ADAPTORS.

16. RDK.

a. The RDK was the first panoramic adaptor furnished the fleet and it aided in filling a very great

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need for an equipment to further analyze intercepted radar signals, to place jamming signals exactly on the frequency of the victim radar's frequency, to discover off-frequency jamming, to discover any shift in the frequency of the victim's radar.

b. The main objection to the RDK was the narrow frequency band width presented on the CRT, 3 mcs. This was too small and, had the enemy been able to shift his radar frequency quickly, the RDK would not have been satisfactory.

c. It is recommended that all RDK's be removed from ships of the fleet and they be replaced by the RDP.

17. REB.

a. The REB panoramic adaptor is superior to the RDK in that it provides a wider frequency presentation of the spectrum selected by its companion receiver.

b. The REB has been quite difficult to align. Misalignment has resulted in only a fair performance, due to non-linearity of response

c. It is recommended that the REB be retained until a satisfactory panoramic adaptor can be procured. An adaptor with a 10 mc presentation is desired, but simplicity of design and construction is essential. Equipment delivered to the fleet must be capable of servicing by technicians of average ability.

18. RDP.

a. The RDP is the latest panoramic adaptor and is scheduled to replace the RDK and REB types. Very few RDP's have been used in action. It is considered that the 10 mc bandwidth presentation will probably be satisfactory for fleet use.

b. When the first RDP's were used, they were found to run hot. This defect appears to have been rectified by the installation of a blower motor on the back of the set. The major difficulty with the RDP's is the lengthy and tedious alignment procedure necessary. The permanence of the alignment of the set is not good. A good technician often requires 3 to 4 hours to align the set

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and in some cases it has been found impossible to get rid of the humps in the response curve.

c. A further study of the design of the RDP should be made with a view to simplifying the process of its alignment and to providing means of vastly improving the permanency of alignment of the set. It is possible that performance may have to be sacrificed slightly in order to get equipment which can be maintained at an operating peak more easily.

DIRECTION FINDING EQUIPMENT.

19. CXGA.

a. The CXGA has been used very little by the fleet. The principal objection to the CXGA was its limited frequency range. This equipment is obsolete.

20. DBM-1.

a. The DBM-1 radar direction finder has not proved entirely satisfactory. The lack of selectivity of the various receivers produces a large number of spurious responses caused by the ship's own and nearby radars. The low frequency antenna has very low sensitivity in the range from 90-250 mcs. This was very unfortunate because the majority of the Japanese radars lay within this frequency range. The physical size of the low frequency spinner antenna is limited by the problems of size and weight aboard ship and is one of the causes of poor performance. Some success in direction finding below 250 mcs has been obtained by use of the rotating TDY antennas. It is possible that with a more directional low frequency TDY antenna it may not be necessary to have a separate radar direction finder as such, capable of taking accurate bearings below 250 mcs.

b. There has been difficulty with own ship's gunfire piercing the radomes. Greater care should be given to the placement of antennas, not only to keep them clear of the arc of gunfire of own guns, but also to give each antenna a relatively unobstructed view through 360 degrees of azimuth in order to reduce a minimum bearing errors due to reflection.

c. It is recommended that research continue to develop antennas for direction finding which will have greater antenna gain, greater accuracy, and more reliability.

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RADAR JAMMING EQUIPMENT.

21. General.

a. Powerful shipboard jamming equipment is needed to cover the entire range of radar. For the next few years, procurement should be limited to those units necessary for experimentation, further development, and fleet training. Size and weight of shipboard radar jammers must be kept to a minimum, but high power output is essential for successful jamming. Most shipboard jammers now available have inadequate power.

b. Airborne radar jammers need further development. The major requirements are: (1) ease of operation, (2) reliability, (3) minimum weight and space, and (4) maximum power output. Frequency coverage of such jammers should keep pace with that of shipboard jammers in so far as practicable.

22. AN/SPT-1 (AN/APT-1) Series.

a. This series of radar jamming transmitters were airborne equipments, modified later for shipboard use.

b. All had relatively low power output, but they were the only available radar jammers when they were delivered. Some were unreliable in operation and others were difficult to tune to the proper frequency. For shipboard use, all are considered obsolete and should be removed from ships of the fleet with the exception of the AN/SPT-1 and AN/ARQ-8. The latter two should be retained on board ship since there are no replacements for them as yet in the greater part of their frequency ranges, which are 90-210 mcs and 25-105 mcs respectively. It is recommended that for aircraft, more efficient and easier-to-tune radar jamming transmitters be developed.

23. TDY, TDI-1, TDY-1a.

a. The TDY radar jamming transmitter was intended to be the ultimate equipment for radar jamming.

b. The original frequency range of the TDY was from 350-770 mcs and was of little use to the Pacific Fleet against the Japanese. However, when magnetrons were delivered to the fleet which went as low as 120 mcs, the

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TDY-1, as it was then named, became an important equipment for radar countermeasures: for providing relatively strong signals to jam enemy radars, to give jamming signals for the AJ training of our own radar operators, and for radar direction finding, because it was found that the low frequency rotating TDY-1 antennas gave good bearings when used in conjunction with the AN/SPR-1 and RDO.

c. A number of difficulties with the TDY-1a have been experienced in the fleet. Too much time is expended changing oscillator units when the order is given to change the jamming frequency. For success of radar jamming operations, it must be possible to shift frequency quickly, which is not now the case. At present it takes about 45 minutes to shift jamming from the 10 mc band to the 120-7700 mc band. A standard modification is required so that the least possible time is required for a change over. Coaxial connectors become loose, allowing dirt and salt spray to enter the connector. This trouble has been experienced with the coaxial connectors to the receiving antennas and the need for some type of moisture-proof covering for the connectors has been demonstrated for all connectors exposed to the weather.

d. The physical location of the TDY antennas has not been satisfactory. It has been necessary to employ duplicate antennas on ships in order to obtain 360 degree coverage. The 10 cm antennas have not been of sufficiently rugged construction and some have been broken due to shock of gunfire. It is considered that a smaller, lighter-weight antenna can be developed which will allow the antenna to be moved up higher. The present locations of most of the RADCM antennas are too low, yet there must be access to them for purposes of inspection and maintenance. Transmitting antennas should be made more directional, not only to provide a greater antenna gain, but to avoid causing interference to our own radars and VHF/UHF radio channels. If directional transmitting antennas are used for jamming, they must be controllable or multiple installations must be provided, with different directional characteristics.

e. It is considered that the size and weight of the transmitter can be reduced, but this must not be done at the expense of the power output. The power output of the TDY-1a and of later equipments should be increased if possible.

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f. It is recommended that future development attempt to decrease the size and weight of transmitter and antennas, to increase the directivity of the TDY antennas as that of direction finding antennas is increased, and to simplify the shifting of frequency.

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Part III

BB and OBB Radar Allowances

Section B

1. Many improvements are very desirable in both search and fire control radar types and characteristics for the newer battleships which will be retained in active service, although the allowed number of radars for each is generally satisfactory as listed in the Radio Type Allowance Booklet RELLIA 100. As a basic principle it is considered that BB's need a number of radars for different primary purposes, capable of limited use for other purposes when casualty requires. The principle of developing one radar to perform all functions is not sound unless several such radars are available on each ship. A fast BB is so dependent on Radar that it cannot afford to depend on a single radar and should have many alternates or spares for each function. For the OBB's, the specified allowance of RELLIA 100 is considered adequate until the ships are placed out of commission.

2. The latest type of long range search radar is considered as important for fast BB's as it is for CV's. The latest type SR with improved antenna should be installed as soon as available. Further improvements should be added as they become available. There is more need in BB for a zenith search radar than there is for a second, medium range, air search. The best type of zenith search radar should be installed in all ships as soon as available.

3. All BB's need two surface search radars: a long range search; and a medium range search and station keeping set that can act as a standby in case of failure to the long range equipment. A third surface radar with very short range and good resolution is desirable for accurate station keeping and close work.

4. An intercept radar of the SP type is very desirable on fast BB's. Depending on the number of SP radars available and estimated production of SX, it may be advisable to install SP in those fast BB's

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which do not already have it. If a radar superior to SP, such as SX, will be available for BB within approximately 1 year, the installation of SP in BB seems unwarranted and SX should be installed instead.

5. The Mark 13 main battery fire control radar should replace the Mark 8 on all BB in active service. The superiority of Mark 13 and the value of having two of the same systems in each ship makes the expense thoroughly justified in this Board's opinion.

6. The Mark 25 should replace the Mark 12 - Mark 22 combinations as soon as available. There is a real need for improvement in all AA fire control radars as soon as practicable. The general principle of one radar system for each separate director system seems sound. Where each mount has a director system, a radar and IFF system should be a part thereof.

7. All fast BB should have the most improved "X" band radar of the Mark 29 or Mark 34 type or better for heavy machine gun control.

8. Most ships feel there is a need for a gunnery officers information and standby radar in the F.C. tower. The Mark 27 is the best now available for this. This Board considers an improved type with variable beam width would be more satisfactory for locating targets and obtaining data thereon, and could also be used as a standby when high level directors and radars become knocked out. This Board believes remote PPI adapter units are desirable for Mark 27 radars.

9. There is a need for a remote PFI of the VF type in both main and secondary battery plots. It is recommended that such installations be made as soon as practicable. A system of close and preferably automatic coordination of search and fire control radars in target acquisition is very desirable. Present use of sound-power telephone for this purpose is inadequate.

10. The installation of radar switchboards in CIC is not recommended for ships already built unless they are given a major modernization overhaul. The system has merit and should be used in new construction.

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6. Cincpac concurs in replacing Mark 12 and 22 radars by Mark 25 radar in the Mark 37 director. However, the Mark 37 director can be improved and it is considered that an integrally designed director and radar system capable of high speed tracking is needed. When a new director and radar system becomes available, Mark 25 radar may become obsolete. It is understood that the Gun Director Mark 56 with integral Radar Mark 35 shows much promise.

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11. Opinion is unanimous that each search and fire control radar should have IFF as an integral part thereof.

12. It is recommended that each active BB, both 80% and 30% complement, have a complete allowance of the latest type of RCM equipment.

13. There is a need for VF remote PPI's in Flag Plots and conning towers. One VF, or possibly one VK or PPI is desirable in the Chart House.

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Part III.

Section C.

Cruiser Allowances.

1. The present allowance of radar and counter-measures equipment for cruisers as given in the Radar Type Allowance Booklet RE11A100 is considered reasonably adequate for all cruiser classes, both active and reserve, for the immediate future except for the need of an efficient zenith search radar.

2. For the near future, for cruisers of the active fleet, it is considered that the present equipment should be replaced by newly developed equipment such as a late model higher frequency SG (8 cm.) surface search radar, a late model SR air search radar such as the SR-3, and a more modern fire control radar such as the Mark 13 and Mark 25. Present equipment on ships of the reserve fleet should also be replaced with the above equipment as production and overhaul schedules permit.

3. To meet the needs of the foreseeable future it is considered that the allowance for cruisers should include the following equipments, meeting the requirements set forth in CNO ltr. (Op-25) Serial 00140225A dated 8 October 1945.

- a. One long range air search radar.
- b. One long range control of interception radar.
- c. A positive IFF system installed on or connected with each search and fire control radar.
- d. Remote PPI or similar indicators at each station where ship control or flag officer's group control may be exercised. Automatic dissemination of information and an instant complete picture of the tactical situation are required.
- e. Complete Automatic tracking fire control radars, both anti-aircraft and surface, for all batteries.

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2. If a new and satisfactory Gun Director and integral radar system becomes available, it should replace the Mark 25 radar and Mark 37 director.

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- f. Countermeasures (intercept and jamming) equipment as dictated by future needs.
- g. One long range surface search radar.
- h. One medium range and station keeping surface search radar.

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Part IV.

Internal Organization and Personnel.

Section A.

Internal Organization of Combatant Ships.

1. Although this Board is not required to comment on the internal organization of ships, the members have encountered so much comment on the pros and cons of certain proposals for the reorganization of ship departments that the following discussion is submitted as being pertinent to post-war planning for CIC and radar development. It is considered that provision of a sound organization for handling electronic and CIC matters in our ships is more important to the progressive development and utilization of radar and radio equipment than many of the materiel questions.

2. Having in mind the shape of things to come in the way of new weapons and countermeasures therefore, it is considered very important that the question of provision of an adequate and improved internal organization of our ships be studied and settled as soon as practicable so that new developments can be efficiently incorporated in our ships.

3. Members of this Board have interviewed the Captains and appropriate officers of a large number of fighting ships. Many of the officers contacted favor sweeping changes; others favor slight changes; very few favor retention of the present organization. There are almost as many different opinions as there are officers. However, a few salient points re-appear in similar form in all discussions. The one point on which almost all officers were agreed is the immediate need for some improvement in ship internal organization to more efficiently handle the new problems imposed by CIC and electronic equipment and by the additional speed and complexity of modern war.

4. Most of the Captains interviewed had apparently made special arrangements or adjustments of their organization to insure the most efficient use of their available personnel based on the individual personalities of their officers. As usual, successful coordination depended on individual interest and ability rather than on details of organization. There appears to be, however, a certain pattern to most of the arrangements which were made as a matter of local expediency. In most changes there appeared to exist an "operations group" whether it was so named or not. There was almost always, separate

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2. Cincpac concurs in the desirability of continued study of and experiment with the internal organization of ships with a view to determining the best working arrangement to meet modern conditions.

3. The fact that opinions differ widely indicates that a very thorough consideration is necessary before complete reorganization is effected.

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from the Executive Officer, an experienced officer who acted as special assistant to the Captain in the matter of obtaining and evaluating combat information. This same officer usually assisted in planning and carrying out operations. The Executive Officer was separately placed to take over in case of a casualty, and was so concerned with administration, training and housekeeping that he had too little time to study and keep track of operations. There was always good officer supervision of damage control. Aboard the aircraft carriers the handling, housekeeping and logistics of the aircraft were controlled by one officer, often the Assistant Air Officer. The Air Officer, sometimes called the Air Operations Officer, devoted his time to planning and executing the airborne operations of the aircraft as distinct from shipboard landing, taking off, reloading, refueling, repair, etc. The CIC's of the carriers were of necessity closely allied with the air department. There was a strong feeling on the part of staff officers and Captains that CIC should be accessible to senior officers and that it should be located in the island if possible. CIC was often used to transmit messages and for other operational functions. On one ship some of the CIC JO's hung a "Western Union" sign over the door. Almost all senior officers appeared to feel that the average CIC tends to soak up information but does not give out necessary information without prodding.

5. In official correspondence, ComAirPac has made certain recommendations, which are concurred by most of the carrier officers interviewed, in that the air department is the defacto operations department in carriers and that the gunnery department should be under this operations department (or operations group) because of the special problem requiring a rapid shift from fighter protection to gunfire protection in defending carrier groups. It has been suggested that the operations group or department of a carrier should include the navigation department, air department, gunnery department, communication department, and the CIC department or division. It is noted that even the opponents of the operational department in carriers appear to group certain departments into an operations group in battle although they administer each department separately. One of the basic difficulties of present organizations appears to be that the duties of the Executive Officer of a large ship, according to Navy Regulations, are so extensive that it is difficult and often impossible

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4. The shortcomings of the average CIC are appreciated. A great portion of CIC officers during the recent war simply had not had sufficient time to accumulate the experience so necessary to complete understanding of tactical problems. This had to be accepted because officers of the requisite background often were needed in other assignments. In the future, it should be practicable to train and provide more experienced CIC officers.

5. Battle organization does not necessarily have to parallel administrative organization. Exercise of the functions of the Executive Officer does not necessarily imply the carrying out of all the details of administration. The entire ship's company are subject to his orders and he should have the assistance of other officers. A poor Executive frequently is snowed under by details; a good one rises above them, utilizing the services of such assisting officers as necessary to permit him to keep abreast of the operational situation so that he will be ready in any emergency to take over the command should the Commanding Officer become incapacitated. No organization afloat is recommended which relegates the Executive Officer to purely administrative functions. There seems to be a tendency in this direction in some of the "operation departments" proposed recently.

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for any one officer to fully exercise all the functions which are now expected of the Executive Officer. Administration problems occupy the Executive Officer so completely that he is unable during war time to coordinate the operational duties and activities of the various departments and can give little or no personal time to the functioning of CIC unless he delegates most of his duties to some other experienced officer.

6. The opinions on battleship and cruiser organizations are varied. The Captains interviewed did not feel the need of an operations department as strongly as in the carriers. Since the primary weapon of these ships is their gunfire, it is natural that CIC has become closely allied with the gunnery department. Prior to the war these ships had the nucleus of the CIC in the old central station-plotting room combination. Although many ships appear quite satisfied to have CIC a part of the gunnery department, others were enthusiastic over the possibilities of an operations department which would include navigation, CIC and communications. An official letter by ComCruDesPac concurs in the CNO proposal to establish an operations department. The need to treat communications as a separate department and have the communication office a head of department was concurred in by almost all officers in the absence of an operations department. Many officers felt that establishment of CIC and look-out divisions as a separate CIC department on a level with the gunnery and communications department was the best improvement which could be made and the simplest change. The CIC officer could then be assistant to the Captain for operational planning.

7. Certain ships already have an experimental operations department which include communications, navigation and CIC. Without exception the official reports from these ships indicate that the scheme has worked well and has definite value in combat.

8. The question of how to handle electronics maintenance under the various organizations was discussed. With the tremendous increase in electronics equipment on all ships during the war it has been necessary to have a large group of officers and men on almost all ships who are concerned solely with the technical operation and maintenance of electronics equipment. Radio maintenance has

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6. It is understood that directives from the Navy Department may be expected in the near future to give the Communication Officer the status of a head of department. Cincpac has previously expressed concurrence in this decision in Cincpac Serial 8840 of 30 August, 1945, and in Cincpac dispatches 012048 and 060350 of Oct., 1945. This step is deemed essential regardless of any future reorganization tending to form a so-called Operations Department.

7. It is considered that the board has read into the reports a unanimity of approval which is open to question. The reports have indicated that such a department will operate satisfactorily, but have not established superiority over the conventional organization.

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occasionally been separated from radar maintenance but often they have been combined under an electronic maintenance group with considerable success. Separation of the two usually resulted in lack of coordination and occasional rivalry. It is the opinion of this Board that each ship should have an electronics maintenance group responsible for the repair and upkeep of all electronics equipment in the ship. This group should be responsible for preventative maintenance in order to insure the optimum readiness and reliability of electronics equipment at all times. This technical group should vary in size with the type of ship and might well be a separate division, somewhat similar to the present E division, on large ships. The electronics division might well come under the CIC or communication department or, better still, under the operations department where such a department exists. The cognizance of some IC systems and announcing systems which are primarily electronics equipment should be transferred from the E division to the electronics division in order to insure adequate maintenance by trained personnel.

9. This Board recommends that final decision for or against the establishment of an operations department be not made at this time. The Board does recommend that the need for improvement in internal organization be recognized and that the matter be kept open and restudied by appropriate agencies with a view to the issuance of appropriate directives on organizational improvement by CNO. Most of the senior officers interviewed on these matters agree that, since opinions are so varied, it will be necessary for CNO to make arbitrary decisions on organization changes and give them service trials prior to final decisions.

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8. Cincpac concurs in the desirability of having a single organized group of electronics maintenance personnel responsible for the care, repair, and adjustment of all electronic equipment.

9. Cincpac serial 05378 of 16 March 1945 commented on the question of creation of an operations department in ships of the Navy giving in some detail reasons for not establishing the operations department. Cincpac serial 07266 of 9 September 1945 and serial 033712 of 26 October 1945 confirm the reasons and reiterate the opinion expressed.

It is again stated here that Cincpac does not recommend an operations department at this time but agrees with the board in considering the problem of ships internal organization an important one deserving further study and experiment.

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Part VI.

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15. CominCh conf. ltr. FF1/S67 serial 02438 dated 18 August 1945.
Subject: Electronic Equipment Requirement for Post-war Fleet.
16. CinCPac conf. ltr. S67 serial 0311 73 dated 19 July 1945.
Subject: Electronic Installation in Ships.
17. USS MISSOURI conf. ltr. BB63/A3-1 serial 086 dated 9 May 1945 with 1st End. ComBatDiv 9 serial 042 dated 9 May 1945. 2nd End. ComBatRon 2 serial 0522 dated 3 October 1945.
18. Secret chart: Planning Organization of the Post-war Naval Forces of the United States dated 1 May 1945.
19. Shipboard Search Radar Program, April 1945 - Prepared by Code 915 Electronics Division BuShips in Compliance with CNO Op-25-A5 serial 0076525A dated 31 March 1945, Electronics Division Directive No. 4856.

Surface Search Radar.

20. ComBatRonTWO conf. ltr. FC1-2/S67-5 serial 0529 dated 6 October 1945 with Enc. (A), CO USS IOWA conf. ltr. BB61/S67 serial 0137 dated 9 September 1943 and 1st End. thereto.
Subject: Radar Plan Position Indicator (PPI) Repeater for Battleship Squadron TWO.

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21. CNO conf. ltr. Op-25-C2/Grm(SC)S67-5/CV, serial 0178225C dated 7 September 1945.
Subject: Class CV-9 Vessels - Removal of Second Air and Surface Search Radar.
22. CNO conf. ltr. Op-25-C2/mfg(SC) S67-5 serial 055525C dated 17 March 1945.
Subject: Radar PPI Repeaters - Installation of in U. S. Naval Vessels - Revision of.

Air Search Radar.

23. CNO conf. ltr. Op-25 C2/mju over (SC) S67-5/CV serial 0216925C dated 28 September 1945.
Subject: Radar - Installation of Model SX in New Construction Carriers.
24. CO USS CATFISH (SS339) conf. ltr. SS339/S67-5 serial 017 dated 25 September 1945.
Subject: SV Radar, Service Operation Performance of.
25. CNO conf. ltr. serial 0197425C dated 25 August 1945.
Subject: SP Radar for new construction, for CVE's.
26. CNO conf. ltr. Op-25-C2/Grm(SC) S67-5/CV serial 0170925C dated 21 August 1945.
Subject: SX Radar, CV-9 Class.
27. CNO conf. ltr. Op-25-C2/gmv over (SC) S67-5 serial 072525C dated 13 April 1945.
Subject: Overhead Search Radar for Large Combatant Ships.

Airborne Search and Intercept Radar.

28. ComAirPac conf. ltr. A16-3(6)NRB/jes serial 06889 dated 13 October 1945.
Subject: Brief of action report USS BELLEU WOOD 2 July to 15 August 1945.
29. Commander Air Support Control Unit Pacific Fleet Top Secret ltr. CASU/A16 serial 00038 dated 6 October 1945 with ComPhibsPac 1st End. serial 000367 dated 13 October 1945.
Subject: Airborne Radar Pickets.
30. CinCPac Pearl Top Secret Dispatch 132057 August 1945.

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Battleship Radar Allowances

The following letters on the subject of Radar and countermeasures equipment from the CO, USS ALABAMA have been considered by this board in making recommendations for radar and countermeasures equipment and allowances for battleships.

- a. CO ALA. ltr. Serial 0401 dated 15 August 1945.
- b. CO ALA. ltr. Serial 0373 dated 26 July 1945.
- c. CO ALA. ltr. Serial 0269 dated 19 June 1945.
- d. CO ALA. ltr. Serial 0242 dated 1 June 1945.
- e. CO ALA. ltr. Serial 0241 dated 1 June 1945.
- f. CO ALA. ltr. Serial 0240 dated 27 May 1945.
- g. CO ALA. ltr. Serial 0237 dated 29 May 1945.
- h. CO ALA. ltr. Serial 0212 dated 7 May 1945.
- i. CO ALA. ltr. Serial 0211 dated 1 May 1945.
- j. CO ALA. ltr. Serial 0199 dated 24 April 1945.
- k. CO ALA. ltr. Serial 0116 dated 1 October 1945.
- l. CO ALA. ltr. Serial 716 dated 28 August 1945.
- m. CO ALA. ltr. Serial 620 dated 25 July 1945.

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- 77. ComCru-DesPac Conf. ltr. S65-7 serial 0646 dated 10 December 1944.
Subject: Coordination of Operational Functions of CIC on board Combatant ships.
- 78. Cominch conf. ltr. FF1/S67-5 serial 03765 dated 8 November 1944.
Subject: Coordination of Operational Functions of CIC on board Combatant Ships.

Books, Pamphlets, Periodicals.

- 79. U.S. Radar Survey Section Nos. 1 through 7, Published by the Authority of the Joint Communications Board of the Joint Chiefs of Staff, December 15, 1944.
- 80. CIC Magazine October 1944 to October 1945.
- 81. ComCruDesPac Suggested Revision to RAD-SIX.
- 82. Radio Type Allowance Booklet RE11A 100 Revision No. 11, dated 1 August 1945.