ORG REPORT

50

A SUMMARY WAR HISTORY OF THE

SUBMARINE OPERATIONS RESEARCH GROUP

Prepared by

OPERATIONS RESEARCH GROUP
OSRD/OFS

UNITED STATES FLEET

1 OCTOBER 1945

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Section A

ORGANIZATIONAL HISTORY

The Operations Research Group was initially organized by Dr. P. M. Morse under the National Defense Research Committee* in April 1942 to assist the Navy, at its request, in analysis of those operational problems, strategic and tactical, which were susceptible to physical, mathematical and statistical analysis. It was under the direct cognizance of the Office of the Commander in Chief, U. S. Fleet. Initially this group of scientists devoted its entire effort to the pressing problems of Anti-Submarine Warfare in the Atlantic. The members of the group were chosen from ranking physicists, mathematicians and actuaries of the country.

The size of ORG grew from an initial six scientists in April 1942 to a strength of about seventy at the war's end, as the Navy found increasing and more varied use for its services. By August 1945 the ORG had five organized subsections which worked specifically on as many different major phases of naval warfare - Submarine, Anti-Submarine, Air, Anti-Air and Amphibious Warfare.

The subsection called the Submarine Operations Research Group (SORG) was born in November 1943 as the result of a request from Admiral C. A. Lockwood, Jr., ComSubPac, to CominCh for an ORG man to be assigned temporarily to his staff to determine whether ORG could be of assistance to the Submarine Force. This request was partly a result of a letter of September 1943 from the Commander in Chief, U. S. Fleet, to the Pacific and Southwest Pacific Fleet commands announcing that ORG personnel could be made available to interested commands requesting such service. Additional motivation was

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* In December 1943 the ORG was placed directly under the Office of Scientific Research and Development for certain minor administrative reasons.

supplied by recommendations of Mr. T. E. Shea of Division 6, NDRC, in conversations with Admiral Lockwood, Commander E. W. Grenfell, and others of the staff in early November 1943 during one of Mr. Shea's official visits to the Submarine Command.

In response to Admiral Lockwood's request, Drs. G. E. Kimball and R. F. Rinehart of ORG went to Pearl Harbor in the latter part of November 1943, Dr. Rinehart to stay on under the auspices of Commander E. W. Grenfell, the Strategic Planning Officer, to survey the prospects of service profitable to the Submarine Force, Dr. Kimball to return to Washington, after a brief study of the situation, to organize whatever Washington ORG assistance to the program seemed indicated.

When Dr. Kimball reached Washington in December 1943, he set in motion the construction of Hollerith punch card codes appropriate for recording pertinent patrol report information in the ORG Washington IBM punch card system to assist in statistical analyses of some of the more evident phases of submarine operations. At the same time a Washington section of SORG, consisting initially of Dr. Charles Kittel, was set up to furnish assistance to the Submarine Operations Research program, and to begin the IBM recording of patrol report data. The Washington section of SORG was responsible to F-4253, the submarine desk in CominCh (then Commander E. E. Yeomans) and to Op23c, the submarine desk in Operations (then Captain A. R. McCann).

By January 1944 it had become evident to the Staff of ComSubPac and to the SORG representative there, that (a) there was considerable prospect that valuable work could be done by SORG and (b) that such work would be appreciably facilitated by an IBM machine installation at ComSubPac. Accordingly steps were taken by ORG to obtain such machines for SORG, Pearl Harbor. The machines were delivered and installed in May 1944.

Although only a part of SORG's work was statistical in nature, it is desirable to outline briefly the nature of the IBM records kept. The punched card system which was set up treated four main phases of submarine patrol experience:

(1) Contacts on enemy surface ships
(2) Attacks on enemy surface ships
(3) Contacts on enemy aircraft
(4) Anti-Submarine attacks by enemy air and surface craft.

In each of these categories most of the pertinent data concerned with each incident could be recorded. In addition, summary information was recorded for each patrol. These files served as a major part of the statistical backbone of SORG records. Because of the great magnitude of the task of catching up on the two years of war patrol data already existing at the time of SORG's inception, it was unfeasible to complete all records for the entire war. However, phase (2) has been completed back to the beginning of the war. Phases (1) and (3) are recorded back as far as the beginning of 1943, although phase (3) was discontinued at the end of 1944. Phase (4) is complete from 1 July 1943 on.

The SORG organizations continued to grow with the expanding horizon of the work, reaching a maximum size in mid - 1944 of five men in SORG-Pac headed by Dr. Rinehart, and six men in SORG-CominCh headed by Dr. Kittel.

According to original plan SORG-CominCh devoted itself primarily to problems of longer range suggested by SORG-Pac, within SORG-CominCh, or by submarine officers in Washington and in SubsLant. SORG-CominCh maintained liaison with Subs-Lant and the Submarine School, as well as with laboratories engaged in submarine developments, and kept SORG-Pac informed on the status of such developments. In addition, SORG-CominCh coded sufficient 1942 and 1943 patrol report data to provide an adequate statistical sampling of early war operations.

On the other hand SORG-Pac, reporting through the Strategic Planning Officer of the Staff of ComSubPac, engaged in problems of more immediate utility to the Submarine Force. It also reported to SORG-CominCh the results of all its studies, suggested long-range problems which needed solution, and, in some cases, suggested equipment developments to be undertaken.

Both groups during their existence were frequently called upon by various officers for specific routine statistical information contained in the punched card files: torpedo expenditures, lists of accomplishments of outstanding patrols, officers and submarines, etc. While the supplying of such information did not represent research effort, it was of appreciable service to the officers concerned.

Since SORG was a part of the larger Operations Research Group, assigned to the Readiness Division, CominCh, SORG shared in the benefits of the services of the larger group. This was particularly true of the Washington unit, which was housed in a part of the suite of rooms occupied by ORG and had readily available the extensive and ever-expanding

reference library of ORG. The IBM equipment and personnel used in Washington were parts of the ORG setup employed for all the sub-groups. The services of various specialists, assigned to the Operations Research Center, such as radar specialists, analytic specialists, etc., were from time to time loaned to SORG to help in various jobs. SORG activities were broadened and often made possible by the fact that SORG was a part of the larger scientific group, which was studying Naval warfare in general. A sample organization chart and directive for the whole group may be found in Appendix A.

SORG Reports

SORG findings were reported in several forms:

1. SORR (Submarine Operations Research Reports) were reports officially published by CominCh, representing studies which were considered in essentially fully completed form. These were given a restricted distribution which included the submarine commands and the concerned Bureaus.

2. SS (Submarine Studies) were unofficially published studies which were disseminated to the interested Commands and Bureaus by F-4253, CominCh.

3. Memoranda were reports whose interest was generally quite special and/or whose security was high, or which represented results of an incomplete study.

4. The Monthly Summary of Submarine Operations was a SORG-produced, CominCh-published, monthly digest of the more important statistics of submarine operations of all commands. This publication also reprinted digests of some selected SORG studies.

To promote a realistic and live viewpoint within SORG as a whole, personnel of SORG-Pac were exchanged with personnel of SORG-CominCh after individual tours of duty of about six months at SORG-Pac. This had the special value of maintaining in the Washington organization a considerable proportion of men who had had close contact with the operating forces. This close contact fostered an appreciation of the submariner's viewpoint which proved invaluable in guiding SORG's work along practical lines. A valuable contribution to this practical viewpoint was provided by the attendance by SORG personnel at command classes of the Submarine School at New London, an opportunity graciously made available by the Officer-in-Charge of the School and taken advantage of at one time or another by nearly every member of SORG. The ultimate in gaining practical experience

occurred when a SORG member made a war patrol on one of the submarines of the Pacific Fleet in early 1945. This experience was highly valuable and instructive, and, from the standpoint of the value it had for operational research, it is regrettable that it was not done earlier in SORG's history.

In January 1945 Dr. F. L. Brooks arrived at SORG-Pac to relieve Dr. Rinehart. In April 1945 the latter returned to Washington to assume supervisorship of SORG-CominCh, where he remained until about a month after war's end. Dr. Brooks continued in charge of SORG-Pac until about a month after war's end.

SCIENTISTS ATTACHED TO SORG DURING THE WAR

Name	Profession	Pre-War Position	At SORG-CominCh From	At SORG-CominCh To	At SORG-Pac From	At SORG-Pac To
Mr.J.M.Boermeester	Actuary	John Hancock Ins.Co.	Nov 44	Dec 44	Jan 45	Jul 45
Dr.F.L.Brooks	Mathematician	Kent State Univ.	Sep 44	Dec 44	Jan 45	Sep 45
Mr. J. Farley	Actuary	Mass.Indemnity Ins.Co.	Jun 44	Nov 44	Dec 44	Jun 45
Mr.E.B.Gardner	Actuary	Metropolitan Life Ins.			Apr 44	Jul 44
Dr.H.Hemmendinger	Astronomer-Physicist	Univ. of Rochester	Nov 44 Sep 45	May 45	Jun 45	Aug 45
Mr.L.A.Holloway	Actuary	Metropolitan Life Ins.	Jan 44	Oct 44		
Mr.F.H.Holsten	Actuary	Metropolitan Life Ins.	Jan 44 Jan 45	May 44 Oct 45	Jun 44	Dec 44
Dr.W.J.Horvath	Physicist	Naval Ordnance Lab.	May 44 Feb 45	Jun 44 Jul 45	Jul 44	Jan 45
Mr.R.J.Jones	Actuary	Metropolitan Life Ins.	Jun 44		Jul 44	Jan 45
Dr.C.Kittel	Physicist	Naval Ordnance Lab.	Dec 43	Jun 45		
Mr.M.J.Klein	Physicist	Columbia U.Grad.Sch.	May 45	Oct 45		
Mr.J.L.Little	Physicist	Case Sch. of Applied Science (student)	Jun 45		Jul 45	Oct 45
Mr.D.C.Peaslee	Physicist	Mass. Inst. of Tech. Grad. School	Jul 45	Oct 45	Dec 44	Jun 45
Mr.J.R.Pellam	Physicist	Mass. Inst. of Tech. Grad. School	Mar 44 Dec 44	Apr 44 May 45	May 44 Jun 45	Nov 44 Aug 45
Dr.R.F.Rinehart	Mathematician	Case Sch. of Applied Science	May 45	Sep 45	Nov 43	Apr 45
Mr. A. Thorndike	Physicist	Milton Academy	Dec 43	Jan 45		
Mr.J.K.Tyson	Physicist	Mass. Inst. of Tech. Grad. School.	Feb 45	Mar 45	Apr 45	Aug 45

SECTION B

OUTLINE OF SORG WORK

1. The account in the subsequent pages is in no sense a history of submarine war. Since it is primarily concerned with the work done by SORG, only those phases of submarine warfare on which SORG did some research are included. Such an account as this, therefore, will mention SORG very frequently. So it is urged that the reader realize that this is simply a history of SORG and that no inference be made that SORG is attempting to arrogate to itself inordinate credit for what assistance it may have rendered.

It is to be emphasized that a very considerable proportion of the credit for the work accomplished by SORG must go to the officers of the Submarine Force, both in Pearl Harbor and in Washington and New London, with whom it was SORG's privilege to work. The valuable suggestions, the open-mindedness, and the hearty cooperation encountered by SORG in its dealings with the Submarine Force can not be over-estimated or over-appreciated. This was, perhaps, even more emphatically true of Admiral Lockwood and his staff, and in particular of Captain E. W. Grenfell through whom SORG-Pac worked during its formative period.

2. SORG's work during 1944 - 1945 was accomplished in two ways, by more or less formal written reports and by personal discussion with interested naval officers and others. Section C summarizes the more important SORG projects and attempts to state briefly the background and the operational significance of each. Because of the large part played by personal contacts, however, it is difficult to evaluate properly in such a summary the actual operational influence which SORG's work exerted. Note, in this regard, the comment at I-C-1, Section C.

3. The projects listed in Section C include formal SORR's, less formal SS's, and more or less informal letters and memoranda. All SORR's and SS's are included in the lists, but only the more important letters and memoranda. SORG accepted a number of jobs whose purpose was historical rather than operational. Those jobs are not listed. The work of the two groups, Washington and Pearl Harbor, was so closely interrelated that no effort is made to separate their projects.

SUBMARINE OPERATIONS RESEARCH REPORTS

SORR # 1 - SECRET - 1 January 1944 - (I-A-2-(a))

Preliminary Statistical Review of Submarine Operations Dec 1941 through Jun 1943.

SORR # 2 - SECRET - 1 April 1944

Effect of Firing Positions on the Success of Torpedo Attacks.

SORR # 3 - SECRET - 1 May 1944

Sightings of Enemy Vessels 1943.

SORR # 4 - SECRET - 1 August 1944

Estimate of Losses of U.S. Submarines Due to Enemy Submarine Action.

SORR # 5 - SECRET - 15 August 1944

Summary of Attacks on U.S. Submarines by Japanese Air and Surface Craft, 1 Jul 1943 to 31 Mar 1944.

SORR # 6 - SECRET - 1 September 1944

Study of Evasive Turning.

SORR # 7 - SECRET - 15 November 1944

Theory of the Effectiveness of Coordinated Attack Groups.

SORR # 8 - SECRET - 20 January 1945

Comparison of Torpedo Performance, Marks 14 and 23 vs. Mark 18.

SORR # 9 - CONFIDENTIAL - 16 July 1945

Effective Submerged Approach.

SORR #10 - SECRET - 20 August 1945

Loss Rates of U.S. Fleet Type Submarines According to Combat Age and an Estimate of the Percentage of Losses Due to Operational Causes.

SORR #11 - SECRET - September 1945

Quantitative Advantage of 20 Knots Submerged Speed for U. S. Submarines.

SUBMARINE STUDIES

SS # 1 - SECRET - 28 March 1944

Contacts with Japanese AH Made by U.S. Submarines During 1943.

SS # 2 - SECRET - 7 April 1944

Japanese Anti-Submarine Measures

SS # 3 - SECRET - 7 April 1944

Variation of Percent Hits with Range for Periscope and Radar Approaches.

SS # 4 - SECRET - 14 April 1944

Effect of Speed on the Safety of Independents and Convoys.

SS # 5 - SECRET - May 1944

Torpedo Salvo Size for Maximum Expected Sinkings per Patrol.

SS # 6 - SECRET - 16 May 1944

Study of Torpedo Track Plans.

SS # 7 - SECRET - 26 May 1944

Grenade Timing and Probability of Flashback.

SS # 8 - SECRET - May 1944

Theory of Zigzag Torpedoes.

SS # 9 - SECRET - 23 May 1944

An Analysis of the First Three Submarine Coordinated Attack Groups to Operate from Pearl Harbor.

SS #10 - SECRET - 3 June 1944

Initial Detection of Submarine by Echo-Ranging.

SS #11 - CONFIDENTIAL - 22 June 1944

Effect of Evasive Action by Target on Probability of a Successful Attack.

SS #12 - SECRET - 11 June 1944

Importance of Visual Sightings.

SS #13 - SECRET - 27 June 1944

Long Range Torpedo Shots.

SS #14 - SECRET - 2 August 1944

Comparison of Submarine Activity of Task Force 17, Task Force 71, and Task Force 72.

SS #15 - SECRET - 25 August 1944

Gunfire Actions by U. S. Submarines.

SS #16 - SECRET - 20 September 1944

Evaluation of Echo-Ranging by Surfaced Submarines.

SS #17 - SECRET - 20 September 1944

Comparison of Operational Results for Various Submarine Types.

SS #18 - SECRET - 23 October 1944

Contacts between U. S. and Jap Submarines.

SS #19 - SECRET - 5 October 1944

Homing on SD Transmissions.

SS #20 - SECRET - 16 October 1944

Effect of Depth Setting on Torpedo Effectiveness.

SS #21 - SECRET - 23 October 1944

Effect of Increased Submerged Speed on Number of Attacks.

SS #22 - SECRET - 7 November 1944

Effect of Depth Setting on Torpedo Running Performance.

SS #23 - SECRET - 4 November 1944

Submarine Torpedo Expenditures in the Pacific.

SS #24 - SECRET - 10 November 1944

"Sono-bombs" Reported by Submarines.

SS #25 - SECRET - 18 August 1944

Coordinated Air-Submarine Convoy Exercises.

SS #26 - SECRET - 9 November 1944

Evasive Routing.

SS #27 - SECRET - 25 November 1944

Enemy A/S Flying.

SS #28 - SECRET - 25 November 1944

Submarine APR-1 Contacts on Jap Radar Stations.

SS #29 - SECRET - 24 November 1944

Yields in Southern Empire Areas.

SS #30 - SECRET - 1 January 1945

Accuracy of Torpedo Fire Control.

SS #31 - SECRET - 23 December 1944

Torpedo Evasion by Submarines.

SS #32 - CONFIDENTIAL - 4 January 1945

Probability and Mk18 Torpedo Prematures.

SS #33 - SECRET - 1 January 1945

Successful Ping Ranges from Submarines.

SS #34 - CONFIDENTIAL - 1 January 1945

Effect of Position of Sun on Submarine-Plane Sightings.

SS #35 - SECRET - 19 January 1945

Increase in Enemy Submarine Threat to U.S. Submarines During 1944.

SS #36 - CONFIDENTIAL - 19 January 1945

Effect of Torpedo Speed on the Success of a Torpedo Attack.

SS #37 - SECRET - 16 February 1945

Relative Effectiveness of Mark 14 & 23 and Mark 18 Torpedoes against Shallow Draft Escorts.

SS #38 - CONFIDENTIAL - 19 January 1945

Preliminary Examinations of Methods of Search from the Flank.

SS #39 - CONFIDENTIAL - 5 March 1945

Are the Japs Homing Effectively on the SD Radar?

SS #40 - CONFIDENTIAL - 9 March 1945

Analysis of Lifeguard Missions.

SS #41 - SECRET - 14 March 1945

Special Procedure for Avoiding German T-5 Torpedoes.

SS #42 - SECRET - 21 March 1945

Comparison of Mark 18 with Marks 14 & 23 Torpedoes in Attacks on Large Warships.

SS #43 - SECRET - 21 March 1945

Successful Submarine Attacks on Warships.

SS #45 - CONFIDENTIAL - 5 April 1945

Air-Sea Rescue Aids and the Submarine Lifeguard Problem.

SS #46 - TOP SECRET - April 1945

U. S. Submarine Losses.

SS #47 - SECRET - 13 April 1945

Japanese Defensive Tactics in Torpedo Attacks.

SS #48 - SECRET - 18 April 1945

Effect of Torpedo Hits on Japanese Merchant Vessels.

SS #49 - CONFIDENTIAL - 25 May 1945

Search from the Flank Compared with Search from Ahead.

SS #50 - SECRET - 15 May 1945

Charge Weight for Submarine Torpedoes.

SS #51 - SECRET - 18 May 1945

Comparative Performance of Light and Heavy Hulled Submarines under Counterattack.

SS #52 - SECRET - 22 May 1945

Submarine Tactics against Mine Fields.

SS #53 - SECRET - 31 May 1945

Effect of Target Coverage on the Success of Torpedo Salvos.

SS #54 - SECRET - 28 May 1945

Target Tracking and Torpedo Aim.

SS #55 - SECRET - 22 June 1945

Operational Data on Japanese Sonar and A/S Tactics.

SS #56 - SECRET - 31 July 1945

A Probable Explanation of the "Light Explosions" Reported by U. S. Submarines.

SS #57 - CONFIDENTIAL - 21 August 1945

Submarine Radar Phantoms.

SS #58 - RESTRICTED - 20 August 1945

Linear Lag in Target's Turns.

SS #59 - CONFIDENTIAL - 22 August 1945

Use of Sound Gear in Submerged Approach.

SECTION C

SUMMARY OF SORG PROJECTS WITH OPERATIONAL SIGNIFICANCE

Part:

I. Strategic and General

- A. Operational Records
- B. Strategy
- C. Special Services

II. Offensive Operations

- A. Coordinated Groups
- B. Search
- C. Approach
- D. Attack
- E. Fire Control
- F. Salvo Spreads

III. Protection of the Submarine

- A. Submarine Losses
- B. Torpedo Evasion
- C. Mine Fields
- D. Sonar Countermeasures

IV. Special Operations

- A. Air-Sub Cooperation
- B. Life Guard Operations
- C. Shoran

V. Ordnance and Equipment

- A. Torpedo Expenditure
- B. Torpedo Performance
- C. Torpedo Design
- D. Submarine Design
- E. Submarine Guns
- F. Radar

VI. Enemy Tactics and Equipment

- A. Anti-Submarine Measures
- B. Radar
- C. Other Equipment

I. Strategic and General

A. Operational Records

1. Punch Card Records

Since complete knowledge of actual operations is a prerequisite of operations research, submarine war patrol reports were analyzed and their information coded and punched on Hollerith (IBM) cards. The resulting file of detached operational information was kept up to date and was drawn on extensively in a number of SORG projects. A complete outline of the information contained on the punched cards with attention to the vagaries resulting from the several changes in coding procedure is being prepared for the reference use of Postwar ORG.

2. Publications

The punch card records were used to provide CominCh and Fleet officers periodically with accurate and up-to-date information on submarine operations. In addition to routine information memos, SORG-CominCh published the Monthly Summary of Submarine Operations, and SORG-Pac prepared a statistical section for the SubPac Submarine Bulletin. Area analysis charts prepared monthly by SORG-Pac were used by the SubPac Strategic Planning Officer. Comprehensive IBM listings of submarine attacks, subdivided by submarine, by command, and by commanding officer, were made from time to time for ranking CominCh and Fleet submarine officers. Detailed information on general features of submarine operations were summarized in two SORR's:

(a) Secret SORR #1 - 1 January 1944

Preliminary Statistical Review of Submarine Operations, December 1941 through June 1943.

(b) Secret SORR #3 - 1 May 1944

Sighting of Enemy Vessels, 1943.

B. Strategy

1. Barrier Patrol in East China Sea

Using the general principles of the barrier patrol, as extended and specialized by ASWORG, a plan for establishing a tight submarine blockade of East China Sea shipping was submitted to ComSubPac(a). The plan was favorably received but was rejected in favor of maintaining a number of coordinated groups in the East China and Yellow Seas.

(a) Secret SORG-Pac Memo - 1 January 1945

Suggested Patrol Barrier Line in the East China Sea.

2. Japan Sea Conditions

As a part of the preparation for the forcing of the Japan Sea SORG-Pac made an extensive and very detailed study of the Japan Sea and its entrances, including air, sea, and land defenses; water and ice conditions; weather; major ports and traffic lanes; evaluation of the entrances; special conditions which might be encountered and special devices needed to handle such conditions; problems created by mine fields; recommended tactics for entrance and exit; assessment of risk; etc. (a). The information was given, both directly and through the SubPac Strategic Planning Officer, to the submarines involved, and a summary of the information was prepared for ComSubPac. The magnitude of the contribution of this work to the great success of the first 1945 Japan Sea operations is difficult to assess; it represented, of course, only a part of the very complete preparations made. SORG-Pac continued throughout the Japan Sea operations to analyze the reports of entrances and exits. Up to date plots of moored mine fields were maintained and made available to subsequent boats departing for the Japan Sea.

(a) Top-Secret SORG-Pac Memo - May 1945

3. Evaluation of Southern Empire Areas

In the summer of 1944 it appeared that certain portions of the Southern Empire waters were more productive than others. Based on several studies of contact rates and ship sizes SORG-Pac recommended in August 1944 a shift in submarine area assignments in those waters (a). This shift was ultimately adopted, and a subsequent study showed that the conditions had continued (b). Opposite recommendations concerning the area around Palau were made early in 1944. Subsequently submarine concentration there was increased.

(a) Secret SORG-Pac Memo - 15 August 1944

Yields in Southern Empire Areas.

(b) Secret SS #29 - 25 October 1944

The Southern Empire Areas during July, August and September.

4. Evaluation of Task Force Activity

The advances of U. S. surface and ground forces caused constant shifting of submarine operating areas, and by the middle of 1944 it became clear that the earlier Submarine Task Force distribution was not best adapted to serve the new operating regions. In connection with the reorganization SORG-CominCh was ask for information on operations of the three Submarine Task Forces (a).

(a) Secret SS #14 - 2 August 1944

Comparison of Submarine Activity of Task Force 17, Task Force 71 and Task Force 72.

C. Special Services

1. Informal Consultation

In a certain measure the formal SORG studies and memoranda were spade work to

dig out information to be used in verbal discussions. It is often difficult, therefore, to convey in a brief comment the operational results of particular projects. This comment should be borne in mind in connection with the projects listed in the summary, for the brief remarks below can not include a complete account of the results of SORG's work.

In addition, the SORG offices, especially at Pearl Harbor, provided a source of advice and assistance on numerous small problems, individually unimportant, but collectively worthy of mention. SubPac and SubTrainPac officers found that SORG files and SORG personnel were frequently able to provide quick information on various phases of submarine operations.

2. Liaison Services

SORG-Pac was able to make a number of non-research contributions to improving submarine operational efficiency or convenience. These were frequently of a liaison nature, arranging for certain information to be given to the submarines, or explaining the principle or use of certain equipment. Much of this work took the form of informal personal discussion. The more formal projects included:

(a) "Loran". Article in SubPac Bulletin (VII, #2) describing principle and operation of Loran equipment.

(b) "What the Hell is a Decibel". Article (written jointly with SubPac unit of New London Underwater Sound Lab) in SubPac Bulletin (VII, #2).

(c) Assistance to SubPac Gunnery Office in setting up a punch-card code for recording and analyzing submarine ordnance failures and defects.

(d) Procurement of RPD (Radar Plotting Device) pictures to assist in navigation by PPI.

(e) Preparation of Grid Charts to facilitate group coordination.

(f) Preparation of shipping contact plots to assist in the planning of patrols.

(g) Preparation of plots of drifting mines (used by MinePac and JicPoa, as well as by SubPac submarines).

3. Intra-ORG

A considerable volume of informal intra-ORG discussion was maintained constantly. On one occasion a phase of submarine operations was studied to obtain information for the use of our own convoy planning. The study showed that the proportion of possible targets actually attacked was more or less independent of target speed up to about 15 knots, and that faster targets were relatively much safer.

(a) Secret SS #4 - 14 April 1944

Effect of Speed on the Safety of Independents and Convoys.

II. Offensive Operations

A. Coordinated Groups

Early U. S. submarine operations were all individual, but the success of U-Boat wolf-packs stimulated the planning of coordinated groups. Three bona fide wolf-packs were organized late in 1943, and their experience, as analyzed by SORG (a), revealed difficulties of communication and effective coordination. Further study, in mid-1944, of groups operating in the spring of 1944 showed that group organization increased the contact rate but that attempts to formalize the coordination of the actual attack tended to reduce the attack efficiency of the individual below the normal. This study (b) recommended the revision of the coordinated attack doctrine, or else the abandonment of attempts to coordinate the attack (i.e., coordinate search but leave the individual submarines more free to conduct attacks). Subsequent doctrine moved in that direction.

In the fall of 1944 SORG presented a theory of wolf-pack effectiveness, indicating that unless homing difficulties could be overcome the use of more than 4 boats in a group would be wasteful (c)(d). U. S. wolf-packs throughout the war consisted of 3 or 4 boats.

(a) Secret SS #9 - 23 May 1944

An Analysis of the First Three Submarine Coordinated Attack Groups to Operate from Pearl Harbor.

(b) Secret SORG-Pac Memo - 10 August 1944

The Extent of Realization of the Advantages of Coordinated Group Operations.

(c) Secret SORG-Pac Memo - 14 September 1944

Preliminary Considerations on Matter of Wolf-Pack Spacing.

(d) Secret SORR #7 - 15 November 1944

Theory of the Effectiveness of Coordinated Attack Groups.

B. Search

1. Tactics

In the early war months submarines operated independently and their search methods consisted largely of the very reasonable procedure of patrolling near traffic concentration points or across convoy routes. Special search tactics became important only when coordination created the opportunity for one submarine to direct other submarines to its contacts - and even more so when aircraft contact reports became available. Given a contact report, what search tactics give the other boats the highest probability of making contact? An evaluation of standard fleet scouting search from ahead, late in 1944, showed that little improvement could be realized by adopting more variable and complicated search plans, and SORG made no recommendation. A study of search from the flank showed that, with more than one submarine available, the chance of contact is improved by assuming different times of enemy's departure rather than different enemy speeds (a). This conclusion was conveyed to the Submarine School, New London. Further study on choice of methods of search was also sent to New London (b). This material was placed on the Command Class reading lists, but few of the boats commanded by 1945 PCO school graduates reached operating areas before the end of the war.

(a) Confidential SS #38 - 19 January 1945

A Preliminary Examination of Methods of Search from the Flank.

(b) Confidential SS #49 - 21 May 1945

Search from the Flank Compared with Search from Ahead.

2. Lookouts

In June 1944 information given by SORG was used to impress on the students of the lookout school at New London the importance of their functions (a).

During the spring of 1945 SORG assisted the lookout school in designing and interpreting tests to determine the most effective rate of scan for night lookouts (b). The results of these tests were promulgated to the fleet as lookout doctrine.

Several other SORG studies dealing with questions related to the training of lookouts were also made (c)(d). Study (c) was prepared as a result of a request from the Medical Research Department of the Submarine School

(a) Secret SS #12 - 11 June 1944

Importance of Visual Sightings.

(b) Confidential SORG Memo - 30 May 1945

Experiments on Rate of Scan for Night Lookouts.

(c) SORG-Pac Secret Memo - 7 September 1944

Information on Surface Contacts on Enemy Surface and Air Forces.

(d) Article in January 1945 MSSO

Statistics on Contact Ranges on Enemy Ships and Aircraft.

C. Approach

Submarine submerged approach tactics have been based on the normal approach course, with "seaman's eye" modifications for positions broad on the target's beam. No formal recognition was taken of the probability of target zigs in cases where the zig plan had not been solved by lengthy tracking. SORG developed an

"Optimum Approach Course" designed to give the greatest chance of reaching attack position against fast, zig-zagging targets, but also useful against any target with a speed advantage over the submarine (a), and a "Minimum Torpedo Run Course", designed to achieve the shortest torpedo run that can be reached from any given position against a straight-running target (b). These courses were given to the Fleet by SubTrainPac and through the Submarine School, New London. SORG-Pac designed a simple modification to the standard Is-Was to find the courses quickly (d), and SubTrainPac prepared modified dials for issuance to the Fleet. The courses were used in combat, but not by all boats. The improvement represented by these courses, while significant, was not major, and actual operating results were not materially influenced.

SORG also studied the theoretical feasibility of submerged approach relying solely on existing sound gear and concluded that unless reasonably accurate ranges were available such an approach was not feasible (f).

(a) Confidential SORG-Pac Memo - 24 December 1944

Submerged Submarine Approach.

(b) Confidential SORG-Pac Memo - 3 January 1945

Achieving the Minimum Torpedo Run.

(c) Confidential SORG-Pac Memo -24 February 1945

Tactical Use of the Optimum Approach Course and the Minimum Torpedo Run Course.

(d) Confidential SORG-Pac Memo - 27 February 1945

Optimum Approach Course Finder.

(e) Confidential SORR #9 - 16 July 1945

Effective Submerged Approach.

(f) Confidential SS #59 - 22 August 1945

Study of Feasibility of Submerged Approach Relying on Sound Gear.

D. Attack

1. Firing Position

A submarine skipper will, if he can, maneuver to attain the most effective position before firing. Any maneuvering at close range necessarily involves some risk of losing the target, either through discovery of the submarine followed by counterattack or evasion, or by unwittingly effective zigging by the target. Consequently it is desirable to evaluate the importance of improving attack position once any possible firing position has been reached. SORR #2, based on 1943 war shots, showed that there was little difference in the success of salvos fired in the arc from 60° to 120° track angles and between 1000 and 3000 yard range (a). SS #3, including 1943 and some 1944 war shots, found substantially constant salvo success rates out to 3000-yard range for periscope attacks and to 4000 yards for night radar attacks (b). A later study (SS #30) analyzed more completely the factors underlying these observations. This information - based on high speed torpedoes - made it apparent that, although short ranges (1000-2000 yards) and normal tracks were desirable, a firing position outside such limits should not be thrown away.

These earlier conclusions did not necessarily apply to the slower electric torpedoes which came into general use during 1944. A 1945 study supported the earlier conclusions about the range of attack using fast torpedoes, and also supported ComSubPac's instructions to get in closer for submerged attacks with slow torpedoes (c).

SORG was asked to evaluate an analysis by a DD officer recommending sharp track angles as optimum for greatest probability of hitting. It was concluded that the analysis was not as accurate or as thorough as other available studies (d).

An early SORG study (e) pointed out that long range shots against convoys were relatively effective, but long ranges against independents were quite ineffective.

(a) Secret SORR #2 - 1 April 1944

Effect of Firing Positions on the Success of Torpedo Attacks.

(b) Secret SS #3 - 7 April 1944

Variation of Per Cent Hits with Ranges for Periscope and Radar Approaches.

(c) How Important is Range? Submarine Bulletin (Vol. II, #2).

(d) Confidential SORG Memo - August 1945

Evaluation of Target Fire Control Analysis by Officer of USS TERRY.

(e) Secret SS #13 - 27 June 1944

Long Range Torpedo Shots.

2. Gyro Angle

Because of the possible variable and uncertain performance of torpedoes on curved shots, and because the range accuracy has considerable effect on the success of such shots, submarines have generally taken whatever time is necessary to maneuver for small gyro angles. Such maneuvering has its cost in terms of deteriorating or lost firing opportunities. SORR #2 (II-D-1(a)) showed that salvo success was independent of gyro-angle up to 40°. This finding was published but

met considerable resistance. Early in 1945 ComSubTrainPac conducted tests with gyros ranging between 70° and 90° which supported the utility of the tactical data on torpedo advance and transfer. Toward the war's end many submarines were accepting large gyros more readily, but, quite properly, nowhere were they used freely as a matter of course.

3. Target Evasion

Target evasion can be either intentional or unintentional - that is, by deliberate action to evade detected torpedoes, or by a zig initiated after the submarine has begun to fire. Some firing positions give the target less chance of successful evasion, and such positions might justify firing even when a zig was expected. Two SORG studies showed that the best position(from the standpoint of target evasion alone) was at 70° to 80° angle-on-the-bow, with about 1500-yard torpedo run or less. This information was made available to the Submarine Command, but its greatest operational value was that noted under III - B, below. Japanese vessels used evasion tactics which showed that they understood the same evasion principles - but that they did not use the most effective protective zig-zag.

(a) Confidential SS #11 - 22 June 1944

Effect of Evasive Action by Target on Probability of a Successful Attack.

(b) Secret SORR #6 - 1 September 1944

Study of Evasive Turning.

(c) Secret SS #47 - 13 April 1945

Japanese Defensive Tactics in Torpedo Attacks.

E. Fire Control

1. General

SORR #2 (see II-D-1) included an attempt to estimate how much of the over-all error in salvo performance was due to tracking and how much to other aspects of fire-control personnel and materiel (including torpedoes). A SORG-Pac study (a) in November 1944 (reprinted as SS #30)(b) studies about 250 salvos fired in the first half of 1944 to analyze in greater detail the effect of range, tracking method, track angle, gyro angle, speed ratio, etc., on firing error. Based on this study a mathematical analysis (c) estimated smaller errors than those of SORR #2. Apparently about half the contribution to the over-all error arises in the tracking solution, and about half from combined errors in fire control equipment (TDC, etc.) and in torpedo performance.

In order to isolate the individual sources of error so far as possible, and where feasible to correct them, Messrs. Duvall and Crout of Radiation Laboratory were asked to apply to submarine fire control a method of error analysis which they had successfully used with PT boats. A project was set up under SORG sponsorship, with the blessing of BuORD, (see (d)) which at the end of the war was still in an early stage of development.

An effort was made, based on New London PCO underway approaches, to isolate the effects of track angles and relative speeds (e). The study seemed to show a systematic error in solution of target course such as to cause a bias towards a miss ahead of the MOT, and a tendency to overestimate low target speeds and underestimate high speeds. Because of special conditions surrounding the approaches, however, the conclusions of this study need to be used with caution.

In January 1945, shortly before the operational introduction of the 20-knot Mark 28 acoustic torpedo, SORG was requested informally by SubTrainPac to consider means for overcoming the difficulty imposed on the fire control problem by the 25-knot minimum torpedo speed setting in the existing Torpedo Data Computer. A simple method of accurate fire control using only the existing TDC was devised and recommended to SubTrainPac. This system was subsequently ratified by the ordnance experts who accompanied the first Mark 28's to Pearl Harbor, and the tactical procedure was disseminated to the Submarine Force in the Submarine Bulletin Vol. II No. II, June 1945.

(a) Secret SORG-Pac Memo - 25 November 1944

The Accuracy of Torpedo Fire Control.

(b) Secret SS #30 - 1 January 1945

The Accuracy of Torpedo Fire Control.

(c) Secret SORG-Pac Memo - 23 March 1945

Torpedo Fire Control Errors.

(d) Confidential SORG Memo - 30 May 1945

Proposal for Study of Submarine Torpedo Fire Control.

(e) Secret SS #54 - 28 May 1945

Target Tracking and Torpedo Aim.

2. Single Ping Ranges

Submarines were equipped from the beginning of the war with supersonic echo-ranging gear. The purpose of the equipment was to aid fire control procedure by the use of a single ping to get an accurate range before firing. Early in the war the skippers hesitated to use the gear for fear of giving away their presence to listening escorts. A study of some thirty ping ranges attempted

during the summer of 1944, however, showed that in no case was the enemy alerted, and that the accuracy of attacks where a ping range was taken tended to exceed the average. With increased confidence in the security of a single ping, with the improvement represented by QB, and with greater understanding of the precautions necessary to assure obtaining an echo, ping ranging became an accepted practice in the later stages of the war.

(a) Secret SORG-Pac Memo - 12 October 1944

Results of Sonar Echo-Ranging by Submarines.

(b) Secret SS #33 - 1 January 1945

Successful Ping Ranges from Submarines.

3. Tracking Aid

A target slows down during any turn, and the resulting "linear lag" can affect the tracking solution. A study of linear lag was not completed until after the end of the war.

(a) Confidential SS #58 - 20 August 1945

Linear Lag in Target Turn.

F. Salvo Spreads

1. Target Vulnerability

Any study of optimum spread is necessarily influenced by the relative value of sinking and of damaging the target (a), and thus on the vulnerability of the target - i.e., its chance of sinking with one hit, two hits, etc. SORG studied the vulnerability of various types of merchant targets to 1, 2, 3, 4, 5, and 6 torpedo hits (b) and, at SORG's request, BuShips prepared an outline of the vulnerability of warships (c).

(a) Confidential SORG-Pac Memo - 2 January 1945

Calculation of Optimum Torpedo Salvo Spacings for Use against Merchant Ships.

(b) Secret SS #48 - 18 April 1945

Effect of Torpedo Hits on Japanese Merchant Vessels.

(c) MSSO - March 1945

Effect of Torpedo Hits on U. S. Warships.

(d) Secret SS #43 - 21 March 1945

Successful Submarine Attacks on Warships.

2. Spread Theory

SORG's first contribution to spread theory was a calculation of the optimum number of torpedoes to fire in a given salvo, as a function of the number of torpedoes aboard, the remaining time on patrol, and the diversity of targets (a). The use of the results of this study depended on a continuous analysis of target density in the area while on patrol. These densities showed sufficient fluctuation that it was felt this study was of long-term strategic application, rather than short-term tactical application. Consequently it was not disseminated to the Fleet.

Study of the optimum target coverage began with SS #30 (II-E-1(a) and (b)), which pointed the relationship between decreasing accuracy and increasing target coverage with increasing range. SS #53 checked that approach (b). A comprehensive study of spread theory was conducted during the spring of 1945, but preliminary discussions at New London raised questions as to the validity of some parts of the first draft. Work was continued intermittently,

as other projects seemed to have greater priority, and the end of the war found the study still uncompleted.

(a) Secret SS #5 - April 1944

Torpedo Salvo Size for Maximum Expected Sinkings per Patrol.

(b) Secret SS #53 - 31 May 1945

Effect of Target Coverage on the Success of Torpedo Salvos.

3. Spread Systems

SORG-Pac, in the course of its informal discussions with submarine personnel, had opportunity to comment on several special spread systems. On one occasion SORG-Pac designed a method of introducing track angle into the Cassidy Spread-Setting Dial, and at the same time designed and submitted to SubTrainPac a spread-setting attachment to the Mark 3 TDC which would allow automatic setting of offsets to spread individual torpedoes by given percentages of target length along the track. These designs were useful only with the Mark 3 TDC, since the Mark 4 had a built-in spread setting device. The designs were not used, and were not formally written up. The only written comment (a) suggested minor improvements to a spread system and spread-setting device developed on USS RUNNER.

(a) Confidential SORG-Pac Memo - 5 June 1945

USS RUNNER Spread System - Comments on.

III. Protection of the Submarine

A. Submarine Losses

An important SORG function was the constant attempt to define and assess the causes of danger to our operating fleet submarines, and the maintenance of a file of submarine losses (a). A study in the early summer of 1944 (b) estimated that enemy submarines had accounted for possibly 70 per cent of all U. S. submarines lost on patrol, and pointed out the great need for some means of effective torpedo evasion. See B below. This study was supported by another (c). Even among "unbelievers" these studies undoubtedly helped produce a greater willingness to put up with the protective inconveniences of the Arma course clock and constant zig-zagging while on the surface, recommended by SORG and adopted by ComSubPac.

Discussions of the situation with the staff of ComSubPac and with Mr. T. E. Shea of Division 6, NDRC, instigated the crash development of a Torpedo Detection Modification of the QB sound head, after it had been demonstrated that a torpedo detector already in existence for merchant ships was inadequate for submarine purposes. Installation of the TDM was on submarines of the Force, was begun on a small scale in September 1944, and by war's end the bulk of the submarines were fitted with this gear. Although not satisfactorily rugged, the equipment was highly valued by submarine skippers, and several have credited it with saving their boats.

A concurrent study of air and surface counterattacks (d) over a sample 9-month period of the war estimated that about 30 per cent of losses were due to enemy anti-submarine surface and aircraft, and showed the relative ineffectiveness of these arms of the Japanese anti-submarine effort. These estimates aroused considerable interest and discussion among submarine officers, many of whom felt that operational losses had claimed at least a few boats. A study of loss rates as a function of combat age of the submarine, completed about V-J day,

supported this view by estimating about 25 per cent operational losses (e). This study uncovered a mortality rate which rose sharply after about 10 patrols. Studies (b) and (c) had assumed certain minimum degrees of equality between Japanese and U. S. submarines. Possibly that assumption in (b) overestimated Japanese fire-control accuracy. A somewhat lower estimate of losses to Japanese subs, however, would still leave them as our submarine's most dangerous enemy.

Early in 1945 it was suggested that [redacted] experience of new skippers might contribute to losses. A study showed the contrary - that the boats with more experienced skippers had the highest loss rates (f). This finding was communicated to ComSubPac.

A study of the trend in submarine losses on patrol showed a peak in 1943 with a markedly decreasing rate in subsequent years, apparently indicating that the Japanese had introduced no effective new anti-submarine tactics or weapons, and that the improved submarine countermeasures to known combat hazards had conspired to make the submarine on patrol in 1945 safer than it had been since 1942 (g).

(a) Top-Secret SS #46 - April 1945

U. S. Submarine Losses.

(b) Secret SORR #4 - 1 August 1944

Estimate of Losses of U. S. Submarines Due to Enemy Submarine Action.

(c) Secret SS #18 - 23 October 1944

Contacts Between U. S. and Jap Submarines.

(d) Secret SORR #5 - 15 August 1944

Summary of Attacks on U. S. Subs by Japanese Air-Surface Craft.

(e) Secret SORR #10 - August, 1945

Loss Rates of U. S. Fleet Type Submarines According to Combat Age and an Estimate of the Percentage of Losses Due to Operational Causes.

(f) Top-Secret SORG-Pac Memo - 19 April 1945

Lost Submarines - Experience of Commanding Officer.

(g) Secret SORG Memo - 10 July 1945 - (Reprinted in July 1945 MSSO)

Rate of Loss of U. S. Submarines to Enemy Action.

B. Torpedo Evasion

1. General Precautions

In view of the danger from enemy submarines (cf. III-A) SORG was requested to evaluate a proposal that submarines echo-range continuously while on the surface (a). The finding was that echo-ranging would attract more attacks than it prevented, unless security of echo-ranging could be assured. SORG-Pac plugged informally, and in a Bulletin Article (b), for full use of the Arma course clock.

(a) Secret SS #16 - 20 September 1944

Evaluation of Echo-Ranging by Surfaced Submarines.

(b) The Increase in Enemy Submarine Attacks During 1944. Submarine Bulletin (II, 2)

2. Evasion of Detected Torpedoes

With realization of the danger from enemy submarines attention was directed to torpedo detection. After the New London Underwater Sound Laboratory developed the TDM, SORG studied the problem of most effective evasion of a detected torpedo. SORR #6 (of II-D-3(b)) had concluded that turning at full speed was the most effective surface maneuver for merchant ships. After special tests at Pearl

Harbor to determine the maneuvering characteristics of fleet submarines (a) a series of SORG-Pac memos developed specific evasion doctrine, which called for diving when range is ample, and turning when range is small, and which applied the doctrine to torpedoes detected on sound gear (b) (c) (d). Memo (d) was republished as SS #31 (e). Dials giving the appropriate action for torpedoes detected at various ranges and bearings were prepared by SubTrainPac and distributed to the boats, to be placed where they could be studied frequently and memorized. Patrol report accounts indicate that more than one boat was saved by use of the doctrine.

Near the end of the war SORG research in connection with T-5 torpedo evasion uncovered a potential improvement of the TDM consisting of modification of the equipment to maintain a constant noise background level at all bearings by a mechanical gain control, thereby preserving a recognizable differential between background noise and the noise of a torpedo with an attendant improvement in ranges of initial detection, particularly abaft the beam. The end of the war has temporarily stopped effort in this direction, but it is expected that the postwar research will treat this question fully.

(a) Secret SORG-Pac Memo - 23 November 1944

Maneuverability Characteristics of Fleet Type Submarine.

(b) Secret SORG-Pac Memo - 23 November 1944

Notes on Calculation of Torpedo Hit Probabilities.

(c) Secret SORG-Pac Memo - 12 November 1944

Evasion Procedure for Avoiding Torpedoes Detected on Modified QB Gear.

(d) Secret SORG-Pac Memo - 23 November 1944

Torpedo Evasion by Submarines.

(e) Secret SS #31 - 9 December 1944

Torpedo Evasion by Submarines.

3. Countermeasures to Acoustic Torpedoes

Submarines en route from East Coast ports to Panama, and in certain Netherlands East Indies waters, ran some risk of encountering German U-Boats which might be equipped with T-5 (acoustic) torpedoes. SORG recommended tactics based on Section 2 above with the added measure of firing a pair of slow torpedoes at the bearing of the U-Boat to act as acoustic decoys (a). When the improved NAE Mark II, with time delay settings, became available it offered an effective but much less expensive countermeasure. SORG thereupon recommended (b) the installation of rocket-launched NAE beacons on submarines exposed to the T-5 hazard. The rocket-launching was found to be feasible, and at the end of the war SORG was assisting both ComSubPac and ComSubLant in tests aimed at developing doctrine for the use of rocket-launched NAE's as countermeasures to T-5 torpedoes expected to be encountered in Japanese hands by as early as September, 1945.

(a) Secret SS #41 - 14 March 1945

Special Procedure for Avoiding German T-5 Torpedoes.

(b) Secret SORG Memo - 23 April 1945

Countermeasures to Acoustic Torpedoes U. S. Submarines.

C. Mine Fields

In ordinary operations submarines were ordered not to enter mineable water without express permission to do so. With the compression of submarine operational areas brought about by U. S. military successes in the Pacific it appeared that Japan Sea operations would become desirable. Early in 1945, SORG-Pac was asked to assist ComSubTrainPac in designing protective gear and tactics to safeguard boats entering mined waters. Operations at mine-case

depth depend on detection of the case itself. SORG did not participate in the design of detection-gear tactics, except for some assistance in designing drill mine-fields for experimental operation. Operation below case depth involves danger of fouling mine moorings, and such danger is least when the submarine's course is parallel to the current. Tentative tactics (a) were followed by more thorough study which revealed that top-side fairing was relatively unimportant, but that effective bottom-side fairing was extremely important (b) and (c). SORG assisted in designing and conducting tests of the mine-cable fairing as installed. A comprehensive statement of tactics and fairing requirements was presented as SS #52 (d) and full information was distributed to the Fleet by the Office of Strategic Planning (ComSubPac) (f). A condensed statement was published in the Submarine Bulletin (e). Boats entering the Japan Sea were equipped with the necessary fairing and carried a summary of recommended mine-field tactics. ComSubPac in May ordered fairing to be installed as a part of every refit thereafter.

(a) Secret SORG-Pac Memo - 15 March 1945

Under-Riding Mine Fields - Tentative Tactics.

(b) Secret SORG-Pac Memo - 9 April 1945

Submarine Tactics Against Mine Fields.

(c) Secret SORG-Pac Memo - 5 May 1945

Fairing Against Mine Mooring Cables.

(d) Secret SS #52 - 22 May 1945

Submarine Tactics Against Mine Fields.

(e) Sub vs. Mine. Submarine Bulletin II - 2.

(f) Sub vs. Mine. A SORG Study. Distributed by Office of Strategic Planning, ComSubPacAd.

D. Sonar Countermeasures

1. Design

In connection with grenade design, SORG made an analysis of the quality of firing

theoretically required to effect a given percentage of successful operation (a).

(a) Secret SS #7 - 26 May 1944

Grenade Timing and Probability of Flash Back.

2. Tactics

Following U-Boat use of Pillenwerfer the submarine force adopted the use of False Target Shells. Early uses of FTS were made under adverse conditions, creating an erroneously low impression of their value. A SORG article in the Submarine Bulletin (a) pointed out the peculiar advantages and disadvantages of FTS, particularly with regard to the Japanese type 3 echo-ranging gear, and endeavored to lift the undeserved blanket of distrust. A SORG memo pointed out that the Japanese type 3 echo-ranging gear would be particularly susceptible to confusion by FTS. (See VI-C-2(a)).

With the development of NAC, NAD, NAE, and other devices, it became important to devise tactics which would obtain the greatest evasion value and avoid actual increase in danger from that use. SORG assisted ASDevLant in the design and conduct of tests to determine the most effective tactics, and in writing recommendations to ComSubPac for sonar countermeasures doctrine (b) and (c). Study of operational data for the purpose of providing background for development of sonar countermeasure tactics showed that Japanese A/S ships (i) used listening in about half the counterattacks on U. S. submarines, (ii) in echo-ranging contacts used Type 93 ER gear primarily, with little Type 3 yet in operation (June 1945), and (iii) made initial contact on the submarine at ranges which permit use of sonar countermeasures on the first run in about half the total number of counterattacks (j).

See also III-B-3, Countermeasures to Acoustic Torpedoes.

(a) False Target Shells. Submarine Bulletin II - 2.

(b) Secret SORG Memo - 25 April 1945

Special Devices for Use by Submarines in Avoiding Detection by Enemy Sonar.

(c) Secret ASDevLant Report - 9 August 1945

Tests of Submarine Evasion Devices.

(d) Secret SS #55 - 12 June 1945

Operational Data on Japanese Sonar and A/S Tactics.

IV. Special Operations

A. Air-Sub Cooperation

The effectiveness of submarines could be materially enhanced if their search rate were increased by coordination with search aircraft. During the summer of 1944, SORG assisted actively in discussions and extensive experimental operations by SubTrainPac and FairWing-TWO, leading to a tentative doctrine for air-sub cooperation (a) [(a) and (b), republished as (c)]. In May of 1945 ComFairWing ONE promulgated for Okinawa-based search planes a doctrine founded substantially on the previous doctrine, and in preparation for such operations two Privateer squadrons were trained at Kaneohe. SORG assisted in the design, conduct, and evaluation of actual test operations involving aircraft, submarines, and a convoy (d). The air squadrons and the doctrine were in operation during the last months of the war.

(a) Secret SORG-Pac Memo - 18 August 1944

Coordinated Air-Submarine Convoy Exercises.

(b) Secret SORG-Pac Memo - 18 August 1944

Aircraft-Submarine Joint Operations - An Analysis.

(c) Secret SS #25 - 18 August 1944 - (A compilation of (a) and (b)).

(d) Secret SORG-Pac Memo - 10 June 1945

Report on Coordinated Air-Submarine Exercises.

B. Life Guard Operations

The organization of air strikes against Japanese-held land targets included provision for life guard craft to rescue downed air crews. Submarines acted as life guards in enemy waters in which our surface vessels could not safely assume the duty. The effectiveness of a life guard submarine is in large measure affected by the treatment it receives from the

aircraft - thoughtless or threatening action by the aircraft, for example, often forced the submarine to dive, thereby literally removing it from station. SORG took an active part in a program to publicize among air personnel, both Army and Navy, the peculiar requirements of the life guard submarine. The program included a lecture schedule, covering a number of advanced bases in addition to Oahu, and informal discussions with responsible air officials. An article written by SORG (a) was widely reprinted by Army and Navy air publications. SORG assisted in tests to determine the feasibility of releasing life rafts from a submerged submarine as a means of rescue in especially dangerous waters [(b) and (c)]. SORG also prepared a number of informational papers on Air-Sea Rescue, including articles in the Submarine Bulletin and two Submarine Studies [(d) and (e)], emphasizing the need for air cover, improved communication, and effective means of homing the submarine to the survivors.

(a) Air-Op Memo (AirPac)

Don't Dunk that Sub!

(b) Confidential Memo - 24 June 1945

(SORG-Pac and CO USS SEARAVEN, jointly)

Second Air-Sea Rescue Exercises to Further Determine Feasibility of Launching Mark 4 and Mark 7 Rubber Life Rafts from a Submerged Submarine.

(c) Confidential SS #40 - 9 March 1945

Analysis of Life Guard Missions.

(d) Confidential SORG-Pac Memo - 18 July 1945

Life Rafts for Submarine Use.

(e) Confidential SS #45 - 5 April 1945

Air-Sea Rescue Aids and the Submarine Life Guard Problem.

C. Shoran

Shoran was developed as a device for increasing the accuracy of aircraft blind bombing by use of ground control radar stations. The 20th Bomber Command, in order to make possible round-the-clock B-29 tactical bombing of Japan regardless of weather and visibility, submitted to the Navy a proposal that submarines be made available to act as Shoran beacon stations. At the Navy's request, SORG made an analytical evaluation of the potentialities of the proposal, both from the standpoint of increased bombing accuracy and from the requirements to be expected of the submarine. The proposal and the evaluation were submitted to ComSubPac who first rejected it, but after further consideration, accepted it. SORG worked out plans for the optimum location of and mode of operation of submarine Shoran beacons and the war's end found eight life guard submarines scheduled to be fitted with the special Shoran equipment.

(a) Secret SORG Memo - 2 June 1945

Possible Use of Shoran Navigational Equipment Installed in Submarines to Assist XX Bomber Command.

(b) Secret SORG Memo for File - 31 July 1945

B-29 Blind Bombing of Japan - Further Discussion of the Submarine Shoran Problem, Including Possible Station Positions.

V. Ordnance Equipment

A. Torpedo Expenditure

As a part of the procurement program, SORG was asked in the fall of 1944 for a statistical statement of torpedo expenditure (a), and submitted a monthly statement of current expenditures to the Submarine Officer in CominCh and to the BuOrd Planning Officer. At the request of the SubPac Gunnery Office SORG-Pac analyzed factors affecting torpedo expenditure and estimated the results on expenditure of the establishment and increased use of advance bases (b).

(a) Secret SS #23 - 4 November 1944

Submarine Torpedo Expenditure in the Pacific.

(b) Confidential SORG-Pac Memo - 22 September 1944

A Method of Calculating Future Torpedo Requirements.

B. Torpedo Performance

1. Comparison

Mark 18 (Electric) Torpedoes were introduced late in 1943 and by the end of 1944 were used in a large proportion of all submarine salvos. There was considerable interest in comparing performance of the faster steam torpedoes with the slower but wakeless electrics. SORG made a comparison of performance against various types of ships, and of the effect of the wakeless feature in protecting the submarine (a). The superiority of the steams was about what their speed advantage should, in theory, produce (cf. V-C-2). The study did not reveal any defensive advantage of the wakeless torpedoes. The study seemed to show that against large warships electric torpedoes performed more satisfactorily than steam, but a subsequent study (b) indicated that such effect was probably the result of statistical fluctuation.

This subject needs more study before the conclusions of (a) can be fully accepted.

(a) Secret SORR #8 - 20 January 1945

Comparison of Torpedo Performance.

(b) Secret SS #42 - 21 March 1945

Comparison of Mark 18 with Marks 14 & 23 Torpedoes in Attacks on Large Warships.

See also II-D-1(c) and V-C-4(a).

2. Depth

SORG studies (a) and (b) showed that against merchant targets the set depth made little difference in the probability of sinking the target, and recommended that torpedoes be set as shallow as considerations of good running permit in order to reduce the danger of under-running the target. During the later months of the war this practice was quite generally followed. An allied SORG study (c) indicated that erratic torpedo running performance was substantially independent of depth setting.

(a) Secret SORG-Pac Memo - 4 October 1944

Dependence of Torpedo Effectiveness on Depth Setting.

(b) Secret SS #20 - 16 October 1944

Effect of Depth Setting on Torpedo Effectiveness.

(c) Secret SS #22 - 7 November 1944

Effect of Depth Setting on Torpedo Running Performance.

3. Prematures

At the request of BuOrd, SORG computed the probability that an observed series of Mark 18 prematures in 1944 was within the range of chance fluctuation, and advised that it was not (a).

(a) Confidential SS #32 - 4 January 1945

Prematures of Mk 18 Torpedo.

C. Torpedo Design

1. Special Torpedoes

German use of Curly and LUT torpedoes stimulated interest in similar torpedoes for U. S. submarine use. A SORG memo (a) outlined the theoretical advantages of a torpedo which could be set to follow a zig-zag course through a given area, and another SORG memo outlined the theory of zig-zag torpedoes (b). At SORG's request the Applied Mathematics Panel studied the theory of zig-zag torpedoes in more detail (c) and recommended attack from ahead using a path consisting of a series of passes normal to the target's course. The study was brought to ComSubPac's attention, but other torpedo developments caused it to be shelved. ASWORG played an important part in the development of U. S. acoustic torpedoes, but SORG had only an informal consulting role.

(a) Secret SS #6 - 16 May 1944

Study of Torpedo Track Plans.

(b) Secret SS #8 - May 1944

Theory of Zig-Zag Torpedoes.

(c) Secret SRG Report No. 338, AMP Report No. 105.1 - October 1944

Efficient Paths for a Zig-Zag Torpedo.

2. Speed and Power

At one time there was a move to stop production of Mark 14-3A torpedoes (with choice of high or low power) in favor of Mark 23's (identical except for elimination of low power feature). SORG pointed out the value of having available a long-range, low-power torpedo for browning

shots at convoys, and asked reconsideration of the conversion to Mark 23's (a). See also II-D-1(e). The two-speed torpedo production was in fact continued, although the Mark 18 subsequently became the most commonly used torpedo.

The comparatively slow speed of the Mark 18 created interest in the effect of speed on the relative offensive value of torpedoes. A study made at the request of ComSubTrainPac (b) showed that, averaged over all targets, 45-knot torpedoes should be about 17 per cent more successful than 30-knot torpedoes, but that 60 knots would be only about 5 per cent better than 45-knots. (See also V-B-1). Near the end of the war SORG was requested to make a similar evaluation of a 100-knot torpedo (not yet finished).

(a) Secret SORG Memo - 17 May 1944

Requirement for Low Power Setting on Torpedoes.

(b) Confidential SS #36 - 17 January 1945

Effect of Torpedo Speed on the Success of a Torpedo Attack.

3. Weight of Charge

See II-F-1 for discussions of target vulnerability. In the spring of 1945 a SORG representative was appointed to an Inter-Bureau Committee to define policy with respect to charge weight. A SORG study made in connection with this work indicated that the lethal effectiveness of torpedoes on standard targets probably increased very slowly with increased weight of explosive, but urged that more experimental research was needed to form definite conclusions (a).

In May 1945 the Office of Research and Inventions of the Office of the

Secretary of the Navy, established a committee to make a long-range study of design requirements in future torpedoes. A member of SORG served in an advisory capacity to this committee to supply operational information and findings pertinent to this committee's work.

(a) Secret SS #50 - 15 May 1945

Charge Weight for Submarine Torpedoes.

4. Fuze Design

A SORG study of target performance showed up the poor results obtained against shallow draft escorts, and, by indicating the probability that this performance was the result of underrunning the target, pointed the need for improved depth-keeping gear or improved fuze design (a).

(a) Secret SS #37 - 13 February 1945

Relative Effectiveness of Mark 14 and 23 and Mark 18 Torpedoes against Shallow Draft Escorts.

D. Submarine Design

1. Size

The late summer of 1944 saw interest in the possibility that small submarines might have a place in U. S. naval planning. A SORG study (a) indicating a marked advantage of our present fleet type over smaller U. S., British and German types was prepared for the use of a committee which subsequently decided against building the smaller boats.

(a) Secret SS #17 - 20 September 1944

Comparison of Operational Results for Various Submarine Types.

2. Hull Strength

A SORG study comparing the performance of light and heavy-hulled submarines when under counterattack showed no significant differences in Pacific operations (a). This was roughly confirmed in SORR #10 (See III-A-C) which showed as a by-product that submarines commissioned before 7 December 1941 had no higher loss rates than those commissioned later.

(a) Secret SS #51 - 18 May 1945

Comparative Performance of Light and Heavy-Hulled Submarines under Counterattack.

3. Speed

On two occasions SORG was asked to evaluate the effect of increased submerged speed on the submarine's ability to attack. An early study indicated that 2 knots greater submerged speed might not increase the rate of attack on all targets by more than 3 per cent (a). A later study (b) of the value of a device giving the submarine 6 hours of 20-knot submerged speed per patrol indicated an expected 23 per cent increase in number of ships sunk per patrol.

(a) Secret SS #21 - 23 October 1944

Effect of Increased Submerged Speed on Number of Attacks.

(b) Secret SORR #11 - September 1945

Quantitative Advantage of 20 Knots Submerged Speed for U. S. Submarines.

E. Submarine Guns

A feeling that guns might not belong on submarines, leading them into more trouble than gun actions were worth, led to a request to SORG for information on the value of gun actions. A study showed that less than 1 per cent of tonnage sunk by submarines had been the victims

of gunfire (a). By the spring of 1945 torpedo targets had become scarce and an increasing number of gun actions against small enemy craft were engaged in by the ever-aggressive U. S. submarines. This led to a request in the summer of 1945 from the SubPac Torpedo Officer for a study to determine whether or not it would be profitable for a submarine to sacrifice one or more torpedoes in order to carry an increased load of ammunition for the deck guns. The study (b) revealed that under the existing relative sizes and frequencies of torpedo and gun targets, it would not be profitable to sacrifice torpedoes for gun ammunition.

(a) Secret SS #15 - 25 August 1944

Gunfire Actions by U. S. Submarines.

(b) Confidential SORG-Pac Memo - 12 July 1945

The Desirability of Additional Gun Ammunition, at the Expense of Torpedoes, for Submarines Patrolling Areas 9 and 12.

F. Radar

Submarine radar, like all radar, and even more than most other equipment, must be maintained and used properly to give best results. SORG played a part, by personal discussions and by memos, in the program of educating personnel to get the best out of their radar for search and for communications. See also VI-B for the question of homing on SD.

(a) Confidential ORG Memo to SORG - 28 October 1944

Sub Communications with Radar.

(b) Confidential SORG Memo - 8 March 1945

Possible Improvement of SJ Communication Ranges.

VI. Enemy Tactics and Equipment

A. Anti-Submarine Measures

1. By Enemy Submarines

SORG studies brought out the extent to which Japanese submarines constituted the most serious threat to our submarines. See III-A-1 (b) and (c). Apparently the Japanese became aware of this unintended development in their anti-submarine war and worked it into their anti-submarine program. Starting about the middle of 1944 there was evidence of intentional anti-submarine use of Japanese submarines (a) independently of other anti-submarine forces, or at most loosely coordinated with them (b). As stated in III-A, these studies did much to spur the development and application of measures to protect our submarines from torpedo attack.

(a) Secret SS #35 - 23 December 1944

Increase in Enemy Submarine Threat to U. S. Submarines during 1944.

(b) Secret SORG-Pac Memo - 5 February 1945

Japanese Submarines and Other Anti-Submarine Forces.

2. General

As U. S. submarines took continued toll, the Japanese increased their efforts to protect their shipping. An increasing proportion of all shipping moved in protected convoys. One effect of increased size of convoys was to lower the percentage of Japanese merchant traffic which was attackable by submarines. (See II-D-b and MSSO June 1945, p. 17.)

SORG attempted to find, by analyzing contacts, whether the Japanese had organized procedures for evasive routing of convoys around positions which were hotbeds of submarine activity. The indication was negative, but the material

available did not permit definite conclusions (a). Later study, not completed, tended to support the view that the Japanese made little effective effort to route shipping away from observed submarine positions (b).

During the first three quarters of 1944 Japanese anti-submarine flying increased about threefold (c). The variation in contact rates with different elevations and angles of tne sun was studied, but without tactical application (d).

An analysis of contacts on hospital ships was made early in 1944 in an attempt to discover any concerted disregard of the Geneva Convention (e). A few probable minor violations were observed, but the majority of observed contacts were in order.

(a) Secret SS #26 - 9 November 1944

Evasive Routing.

(b) Confidential Memo for File - 23 July 1945

Further Study of DF'ing of Submarine Radar.

(c) Secret SS #27 - 25 November 1944

Enemy Anti-Submarine Flying.

(d) Confidential SS #34 - 1 January 1945

Effect of Position of Sun on Submarine-Plane Sightings.

(e) Secret SS #1 - 28 March 1944

Contacts with Japanese A.H's Made by U. S. Submarines during 1943.

B. Radar

1. Location and Analysis

SORG-Pac worked with the SubPac RCM Officer to analyze the sources of radar interference and receiver intercepts observed by submarines. Two memos suggested explanations for two such observations: signals in the 250-265 mcs band were explained as probably originating in the SJ of other submarines as a result of higher harmonics of the local oscillator in the APR intercept equipment (a) and 25 mcs intercepts in the East China and Yellow Seas were attributed to a German type Ruffian navigation aid on Saishu To (b). A later memo (c) pointed out that the former (a) may have been in error, since there was evidence that the Japs had shipborne radar at 265 mcs. Study (a), however, recommended that a detailed report on radar intercepts be included in patrol reports. That recommendation was adopted.

Observed intercepts were analyzed to locate enemy land-based radars. A preliminary study determined the feasibility of such a process and recommended tactics for avoiding detection by known stations (d). A later study listed radar locations, giving type and characteristics, and observing that the Japanese possibly made air-warning radars do double-duty as surface search (e). Subsequently this type of study was abandoned because it was adequately taken care of by JICPOA and the RCM section of CinCPac.

A submarine on patrol does not always know the exact location of friendly boats in the neighborhood. Consequently SJ and SD interference from friendly subs was frequently attributed to enemy radar. SORG studied a segment of these interference reports in great detail, checking them against the positions of all other submarines, to determine what intercepts

originated from friendly units and which from enemy (f). The great majority were from friendly subs, ships, or aircraft. A few definitely were of enemy origin, but under circumstances indicating that either the interference was a result of higher harmonics of a lower frequency than S-band or Japanese shipborne S-band radar was relatively inefficient. Special analyses were made of individual incidents which had attracted considerable attention, but which turned out to be interference from other SJ transmitters. For example, (g).

(a) Secret SORG-Pac memo - 21 November 1944

Origin of 265 Megacycle Signals Detected by U. S. Submarines.

(b) Secret SORG-Pac Memo - 15 November 1944

Japanese Navigation Aid in the Yellow Sea.

(c) Secret SORG Memo - 4 January 1945

Japanese Radar and Navigational Aid.

(d) Secret SS #28 - 25 November 1944

Submarine APR-1 Contacts on Japanese Radar Stations.

(e) Secret SORG-Pac Memo - 24 December 1944

Japanese Shore-Based Radar Stations Detected by Submarines in the Nansei-Shoto, Yellow Sea, and Southern Empire Regions.

(f) Secret SORG-Pac Memo - 4 January 1945

The Sources of Radar Interference.

(g) Secret SORG-Pac Memo - 8 January 1945

SJ-Radar Interference Encountered by Sailfish, Parche and Pomfret on 15 November 1944.

2. Homing on SD

Submarine personnel were acutely aware of the radar waves transmitted by their equipment, and large-scale Japanese use of equipment in the same general frequency range as the SD gave rise to fears of DF'ing and homing on SD transmissions. Individual experiences that could suggest homing by aircraft were widely interpreted as definite proof of homing, and many submarines severely curtailed the use of SD, or even secured the set completely. A preliminary SORG study in October 1944 (based, however, on a small volume of data) found no indications of effective homing, and even suggested that submarines not using SD might have experienced a higher rate of aircraft contacts and counterattacks. Later studies, made when more data became available, supported the earlier indications establishing that no effective Japanese homing on the SD radar, as it was currently being operated, had existed up through the end of 1944 and indicating that submarines using the SD radar were actually somewhat safer from attack by enemy aircraft than those which secured the SD [(b), (c), and (d)]. An active campaign of personal discussion and of publicity (e) somewhat revived confidence in the use of SD, and led to actions designed to prevent the unwarranted discrediting of future equipment. The entire incident had an important bearing on the 1945 revival of the SubPac Submarine Bulletin as a means of combating scuttlebutt by providing a medium for disseminating authentic information to the fleet (f).

(a) Secret SS #19 - 5 October 1944

Homing on SD Transmissions.

(b) Confidential SORG-Pac Memo - 30 January 1945

Are the Japs Homing on the SD?

(c) Confidential SORG-Pac Memo - 17 February 1945

Are the Japs Effectively Homing on the SD? (Further Study).

(d) Confidential SS #39 - 5 March 1945

Are the Japs Homing Effectively on the SD Radar?

(e) Are Jap Aircraft Homing Effectively on the SD? Submarine Bulletin II-1.

(f) Secret SORG Memo - 17 April 1945

Purpose and Value of the Submarine Bulletin.

3. The Nansei Shoto Ghost

Submarines in the China Seas, especially around the Nansei Shoto, were frequently bothered by phantom pips which either refused to materialize on the ocean or which caused the submarine to dive for fear of aircraft or PT boats. These ghost radar echoes became an operational problem, and various high-flown explanations of their cause were advanced (c.f. CIC Bulletin, March 1945). On a few occasions bird flocks were observed at the range and bearing of the phantom pip. SORG obtained information on the habits of Nansei Shoto bird life from a professional ornithologist, and by comparing that information with the conditions obtaining at the time the pips were observed, determined that up to 80 per cent of the phantoms were probably

caused by birds. Surprisingly, a large proportion of the remaining non-bird pips were probably second trip echoes not so identified by the radar operator!

(a) Confidential SS #57 - 21 August 1945

Analysis of Correlation between Habits of Birds and Characteristics of Radar Phantoms.

(b) SORG Memo for File - 21 June 1945

Data on Birds of the China Sea and Japanese Empire Waters.

C. Other Equipment

1. "Sono-Bombs"

Submarines occasionally heard peculiar small explosions, not heavy enough to cause damage. One suggestion of cause was a "sono-bomb" designed to create sonic waves which would give an echo discernable in sonic listening gear, thus assisting in locating the submarine at presumably great ranges. An early SORG study (a) pointed out that more information was needed before the sounds could be identified with confidence. SORG undertook to arrange that records of various underwater sound be distributed to the fleet for indoctrination. Another study (b) summarized U. S. experiments with a similar explosive echo-ranging procedure, which had been stopped because of unsatisfactory results, and this study suggested that many of the sounds might have been caused by gunfire. A final note (c) on the type of sound heard by the submarines suggested that in many cases it may have originated from the Japanese "Mark 4 Emit Noise Missile", to which captured documents referred as being thrown overboard by vessels under threat of attack. (As an interesting sidelight, German U-Boat skippers occasionally reported similar sounds in the Atlantic, attributed by them to the propellant charge of Y guns.)

(a) Secret SS #2 - 7 April 1944

Enemy Anti-Submarine Measures.

(b) Secret SS #24 - 10 November 1944

"Sono-Bombs" Reported by Submarines.

(c) Secret SS #56 - 31 July 1945

A Probable Explanation of the "Light Explosions" Reported by U. S. Submarines.

2. Sonar

SORR #5 contained considerable information on the Japs' use of listening and echo-ranging equipment, and on its efficiency as a means of directing attack on our submarines. [See III-A-1(d)]. SS #55 summarized intelligence on Japanese sonar equipment in connection with the planning of countermeasures. [III-D-2 (d)]. SORG was instrumental in arranging for evaluation from captured documents, of the Japanese Type 3 echo-ranging gear. Based on that evaluation, a SORG memo pointed out that FTS would be particularly effective against that equipment (a). Another SORG memo had showed that, of all cases of detection leading to counter-attack by Jap surface vessels, only 3 per cent of initial contacts were made by echo-ranging (b).

(a) Secret SORG Memo - 31 January 1945

False Target Shells as Countermeasure to New Japanese Echo-Ranging Gear.

(b) Secret SS #10 - 3 June 1944

Initial Detection of Submarine by Echo-Ranging.

3. JITAN (Jap MAD)

Starting in the latter part of 1944 Japanese planes were occasionally seen

flying very low over the water, apparently searching for submarines. Concurrently PW's began mentioning JITAN, a magnetic airborne submarine detector. Based on U. S. experiences with MAD, and on a report evaluating Japanese equipment, SORG outlined tactics to minimize the already-low chance of detection (a); the information was distributed to the fleet by way of the SubPac Submarine Bulletin (b).

(a) Secret SORG Memo - 21 February 1945

Effective Tactics against Japanese MAD Equipment. Submarine Bulletin II-1.

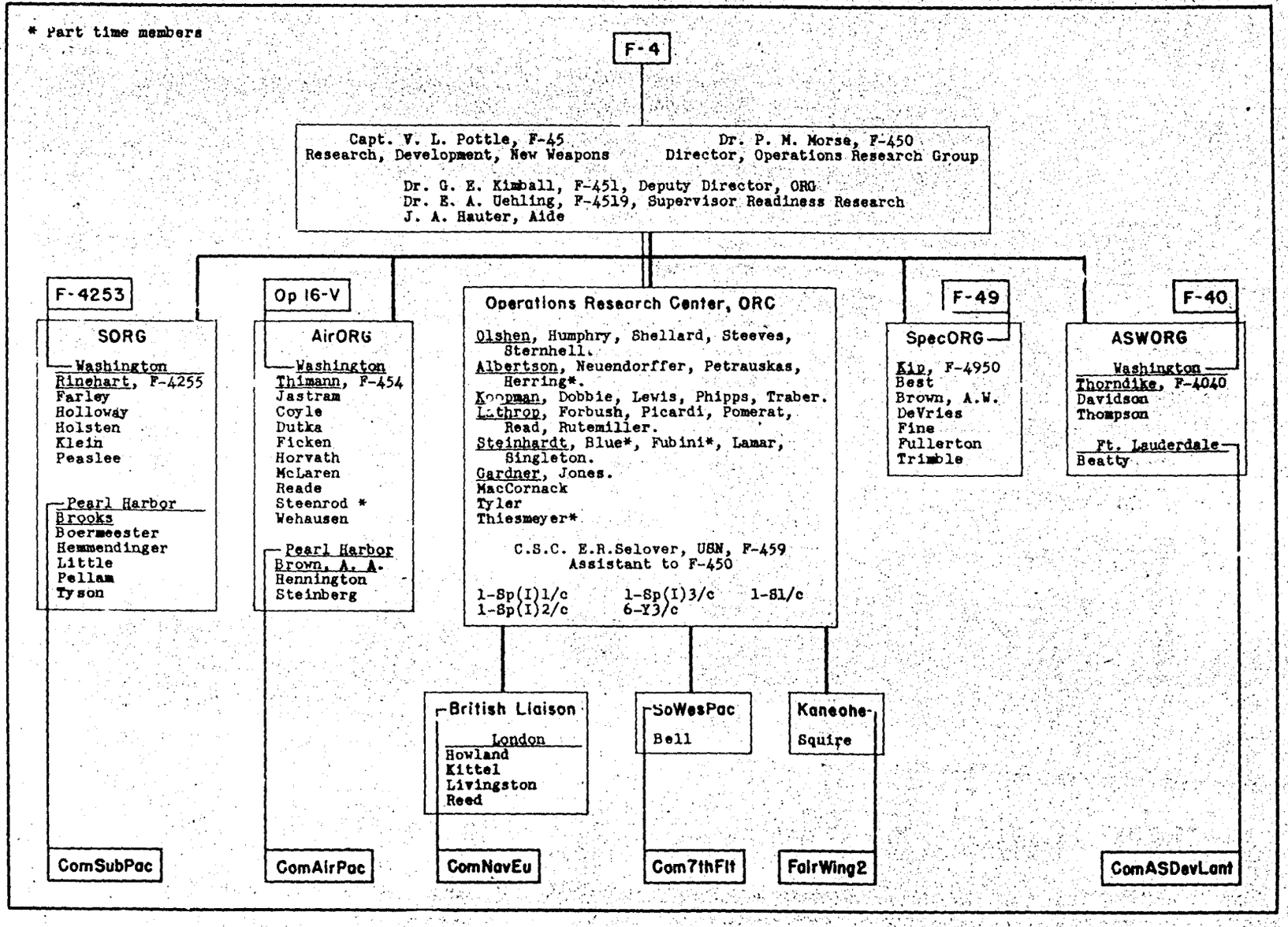
4. Aircraft Searchlights

Two instances early in 1945 suggested the possibility that Japanese aircraft equipped with searchlights might join their anti-submarine forces. In a Bulletin article SORG evaluated the threat in the light of U. S. A/S searchlight experience and our knowledge of Japanese airborne radar capabilities, and was able to assure the fleet that with current enemy equipment the possible development was a very slight threat.

(a) A/S Aircraft Searchlights. Submarine Bulletin II-2.

APPENDIX

A



ORGANIZATION OF OPERATIONS RESEARCH GROUP

15 JULY 1945