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SUBMARINE-VS.-SUBMARINE EXERCISES

Report of the
Defense Science Board ASW Task Force

12 April 1968

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Office of the Director of Defense Research and Engineering
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MEMBERSHIP

of

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OFFICE OF THE DIRECTOR OF DEFENSE RESEARCH AND ENGINEERING
WASHINGTON, D. C. 20301

22 April 1968

TO: THE SECRETARY OF DEFENSE

THROUGH: THE DIRECTOR OF DEFENSE RESEARCH AND ENGINEERING

This report, "Submarine-vs.-Submarine Exercises," is the second of several to be submitted by the Antisubmarine Warfare Task Force of the Defense Science Board. It contains a number of recommendations that the Defense Science Board considers worthy of the most serious consideration in planning and programming our ASW weapon systems. The Board has been especially impressed with the great need for better submarine-launched attack weapons than those now possessed by the fleet.

The recommendations are presented in the first few pages of the report. I commend them to your attention.

R L Sproull
Chairman,
Defense Science Board

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OFFICE OF THE DIRECTOR OF DEFENSE RESEARCH AND ENGINEERING
WASHINGTON, D. C. 20301

12 April 1968

MEMORANDUM FOR THE CHAIRMAN, DEFENSE SCIENCE BOARD

SUBJECT: Submarine-vs.-Submarine Exercises, Report of the Defense Science Board ASW Task Force

The ASW Task Force of the Defense Science Board herewith submits its final report on submarine-vs.-submarine exercises.

In summary, the exercises reveal an alarming situation with respect to the Navy's antisubmarine submarine capability; that is, the Navy lacks suitable weapons with which to capitalize on its submarines' quietness, great mobility and sophisticated sonar. The exercise results hold strong implications regarding characteristics of the weapons required. The Task Force's first two recommendations concern this vital matter and are of the highest urgency.

Recommendations 3 and 4 deal with techniques for extracting maximum value from these expensive at-sea trials, and our last recommendation addresses the matter of decoys for trail breaking. Although our report does not include a recommendation to develop a system for secure underwater communication between submarines, several members of the Task Force believe that one is needed and that, based on today's technology, such a system is feasible if the data-rate and range requirements imposed are realistic. These matters are less urgent than those addressed in recommendations 1 and 2.

To facilitate the carrying out of its recommendations, the Task Force will be happy to consult with the ODDR&E staff.

E. E. David, Jr.

E. E. David, Jr.
Chairman

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ACKNOWLEDGMENTS

The Task Force deeply appreciates Rear Admiral P. A. Beshany's great assistance and encouragement in this study, and we thank Commodore M. Moore and Commodore W. Pugh for their hospitality during our visits to New London. Further, the fine cooperation of the officers of Submarine Development Group Two was an essential contribution to our work.

CONTENTS

CONTENTS (continued)

Page

Figure

Tables

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1. THE TASK

The assignment of the Defense Science Board ASW Task Force was as follows:

> The Navy has underway a continuing series of at-sea exercises to aid in the evaluation of our ASW capability. Emphasis in the past two or so years has been on exercises to determine how effective our attack submarines will be in establishing and maintaining ASW barriers. Much has been learned in this time, but significant questions remain regarding the effectiveness of our attack submarines. Specifically, there is the question of whether the Soviets could employ their relatively large numbers of conventional and "noisy" nuclear submarines in manners different than we have assumed, and whether such differences may change conclusions regarding our relative capabilities. Tactics such as counter-barriers, submarine "mine" fields, saturation penetrations and other coordinated operations have all been mentioned.
>
> I would like the Board to review the results of past exercises to assess their validity in the light of these remaining questions. Specifically, I would like comments from the Board as to what may reasonably be concluded with confidence from past sub vs. sub exercises, and whether additional exercises are needed to answer the remaining important questions, particularly those raised by the many vs. one situation. In this assignment it is important to consult with U.S. Navy officers who have experience in planning and executing "Soviet" submarine strategy in fleet exercises and effectiveness studies. Try to think like the Soviets on the question of how to best use their large quantity of submarines. I caution the Board to consider the difficult problem of providing adequate submarine services for such exercises, and the consequent desirability of using at-sea exercises only when the factors to be investigated are of sufficient importance, and when alternate means of investigation--studies or more limited equipment tests --are not adequate.[1]

[1] John S. Foster, Jr., Director of Defense Research and Engineering, "ASW Task Force Subtask: Submarine vs. Submarine Exercises," memorandum dated 30 November 1966 for the Chairman, Defense Science Board.

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2. RECOMMENDATIONS

Having completed its study of the Navy's submarine-vs.-submarine exercises at sea, the Task Force believes that there are major and perhaps fatal gaps in the antisubmarine capability of our submarines and that these gaps center in the area of weapons. The Task Force presents the following urgent recommendations:

1(a). *A long-range, submarine-launched, nonnuclear weapon with a short delivery time should be developed.* It should be based upon a redesigned SUBROC vehicle with the Mark 46 torpedo as a homing warhead. We understand that a study on the feasibility of mating these two units indicates that no unavailable technology is required. Cost and timing have not yet been estimated accurately, but figures of $50 to $100 million and 24 to 36 months have been mentioned. Both should be minimized by imposing only essential requirements on the new weapon. In particular, the following performance is entirely adequate for the first version:

Maximum depth of launch -- 200 feet
Maximum range ------------ 30,000 to 40,000 yards
Maximum launch speed ----- 5 knots

In the opinion of designers, to require greater performance would delay the development. Moreover, to make the weapon available more quickly, production should parallel the test firing program, which is a major time consumer in the development.

With a weapon of this kind, our SSKs should be capable of attacking from beyond counterdetection range. This capability would also increase the SSK's target-handling capacity and lessen its vulnerability to counterattack. Thus, two problems might be relieved to some extent—the possible enemy use of saturation tactics (section 3.1.1) and the sensitivity of our force-effectiveness estimates to variations in assumptions (section 3.1.2).

1(b). *Development of a medium-range (10,000 yards) torpedo effective against surface targets should begin at the earliest possible time.* The surest development path at the moment is adaptation of the Mark 45 nuclear torpedo to carry conventional explosive. Studies indicate that this weapon could be available in 2 years at a reasonable cost. It could have midcourse guidance and a rudimentary passive-homing capability. This entire matter has been studied at length by the Navy, and action should be initiated immediately. An alternative course, adapting the Mark 48 for surface use, is a less certain path.

In the longer time frame, consideration should be given to developing, for use against surface targets, a long-range SUBROC-type weapon with an air-homing warhead. The Task Force believes this is an especially promising possibility.

A small, short-range, less costly weapon is needed for use against quiet submarines. A weapon of the Mark 46 type, to be launched from a torpedo tube, should be considered. Again, cost and timing have not been determined, and *a feasibility study should be undertaken.*

2. *Tactics and operational doctrine relating to the use of active sonar in fire control for the recommended long-range nonnuclear weapon should be developed.* The meager data we have today indicate that ranges between 30 and 70 kiloyards are quite feasible. Refined information of this kind should be fed into the development program recommended so that weapon and fire-control ranges will be compatible.

3. *At-sea trials should be extensively supplemented by the use of simulation models that have, themselves, been validated in exercises at sea.* At least three separate attempts to develop suitable models are in progress. SUBDEVGRU (Submarine Development Group) TWO has a modest contractual effort of this kind (about $200,000 per year), and interesting results are being obtained[2]. At the present time, this effort is not limited by funding, and no augmentation is recommended. The Tactical Analysis Group of SUBDEVGRU TWO has been expanded from 7 to 11 people in the past year, which gives an adequate core for data analysis and tactical modeling. A growth rate of one or two people annually for the next few years is appropriate.

The lack of computing facilities severely limits the utility of simulation to this Group as an aid in reducing the required time at sea and in sharpening the issues to be resolved by the exercises. *The Task Force recommends a major expansion of the computing center at the New London Submarine Base*, so that it can serve SUBDEVGRU TWO in addition to filling the training and logistic needs of the Base.

4. *Data recording during at-sea exercises should be automated.* The data tapes should be compatible with the direct-input channel of the computer. Present manual methods of recording data impede the operators during the exercises, and the data are sometimes incomplete. Automated recording would alleviate these problems and also would facilitate the reconstruction and analysis of the exercise, which at present are slow and unable to keep pace with data acquisition.

5. *Trail-breaking decoys should be investigated with a view to enabling U.S. submarines both to break away when being trailed and, on being confronted by decoys when trailing, to resist diversion.* Exercises to further this investigation are well justified.

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[2]Klingman, Elmer and Makonechny, *The Military Payoff of Silencing a Forward Area Barrier Submarine* (New London: Office of the Technical Director of Military Effectiveness, Div. Tech. Note OTD-074-6, 5-4627X, August 1967).

3. CONCLUSIONS BASED ON RESULTS OF THE EXERCISES

Thus far, the Navy's at-sea exercises have been designed to investigate two operational concepts:

(1) The antisubmarine submarine (SSK) as a forward-area barrier against transiting submarines and

(2) The submarine as a trailing vehicle against submarines both transiting and on station.

The exercise results relevant to both concepts lead the Task Force to the conclusions presented here.

3.1 The SSK as a Barrier

3.1.1 Tactics: The outcome of a submarine-vs.-submarine engagement is critically dependent upon the relative noise levels, sonar performance and weapons effectiveness of the antagonists. In most of SUBDEVGRU TWO's submarine-vs.-submarine exercises, the SSK was so superior to the transitors in noise and sonar performance that the influence of coordinated enemy tactics involving up to five transitors and intruders—which were prepositioned, quiet submarines—was not evident.

Apparently, tactics such as these cannot offset a large disparity between the adversaries' noise levels, sonar performance and weapons effectiveness. In the exercises, any small influence of these tactics on results was masked by large disparities in noise level and sonar performance.

This conclusion, however, would break down if a great number of adversaries were to saturate the SSK's target-handling or weapons capability. This situation might occur, for example, in the first-deployment phase of a war. To cite an extreme case, the enemy might successfully send his force of noisy, "deaf" submarines through one barrier area *en masse*, saturating the SSK's capabilities and killing the sub. A crude calculation indicates that as many as 190 submarines might be so deployed with the loss of only 10. Also, NEWCLOPS simulations at the Naval War College indicate that saturation tactics can be effective.

Saturation tactics of this kind, of which a variant could be highly effective under some circumstances, are not used in the Navy's exercises.

3.1.2 Sensitivity of Estimates: It is estimated today that Soviet submarines, with the possible exception of those that operate on batteries, are much noisier than U.S. subs of the PERMIT class. The Soviets are credited with sonar performance equivalent only to the U.S. Navy's AN/BQR-2B. Finally, using the U.S. Mark 37 as a basis for comparison, the Soviets' torpedo capability is assumed to be no better than ours.

Only if these estimates are precise would the PERMIT-class submarines achieve their predicted effectiveness as SSKs against the Soviets—that is, a kill probability of .20 to .50 per transit and an exchange ratio greater than 5:1.

Indeed, our force effectiveness appears to be quite sensitive to variations in these assumptions. Exercises indicate, for example, that a 14- to 20-decibel reduction in the radiated noise level of a transitor (from SEAWOLF to SKIPJACK level) lowers the exchange ratio between single adversaries from greater than 50:1 to 2.8:1 and reduces the probability that the SSK will destroy the transitor from .20 to .075.

Another evidence of this sensitivity appeared in exercises under atypical sonar conditions that tended to equalize the sonar performance of transitors and SSK. In these circumstances, a coordinated force of quiet (battery-operated) submarines, whose sonar performance equaled that of the PERMIT-class SSK, stood off the barrier sub and achieved a nearly 1:1 exchange. This suggests that submarines with SKIPJACK characteristics, given an improved sonar, an effective weapon and appropriate cooperative tactics, could prove to be formidable opponents to PERMIT-class SSKs.

The exercise results also point to another possibility, that the Soviets might gain a capability against a PERMIT-class barrier by using their large numerical advantage. To attack the barrier submarine, they might quiet the battery-operated mode of their diesel-electric submarines and retrofit an improved sonar. Conceivably, such a program could produce an effective anti-SSK submarine for the Soviets.

3.1.3 New Weapons: The exercises point to the vital importance of reliable and versatile weapons in a submarine-vs.-submarine engagement. Today's assumed advantages of the PERMIT class over Soviet boats would be vitiated if a high percentage of their attacks were unsuccessful because of torpedo malfunctions or countermeasures. (At-sea exercises of submarine vs. submarine have not been carried beyond the first-shot stage. Continuing engagements have not been investigated; but the re-attack situation has been treated in the NEWCLOPS war-game simulations, and in them the crucial role of a reliable weapon was evident.) Trials of the Mark 37 torpedo by SUBDEVGRU TWO indicated that it lacks the qualities of an effective weapon for the PERMIT-class SSK.

The development of the Mark 48 may redress this situation, but *the exercises point to the potential advantages of new weapons.*

The SSK detects Soviet submarines much farther away than counter-detection range. Yet, to fire its weapon, the SSK must close to within a few thousand yards, exposing itself to detection and counterattack[3].

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[3]The Task Force has been told that, under operational circumstances, the Mark 48 ordinarily would be fired from 12,000 yards or less. Its running time on a dogleg course would be over 10 minutes. The present Mark 37 weapon is usually fired from within 5,000 yards.

Indeed, in SUBDEVGRU TWO's exercises, most counterdetections occurred during the final phases of the SSK's approach and attack.

This situation points to the need for a long-range, short-delivery-time, nonnuclear weapon—for example, the SUBROC using a conventional warhead with homing. [redacted] Such a weapon would enable the SSK to engage its adversary beyond passive counterdetection range and, presumably, out of countershot range. As demonstrated in SUBDEVGRU TWO's exercises, a standoff weapon's fire could be controlled by active sonar or by an improved passive ranging technique now being investigated by that Group.

For close engagements, a high-speed, short-range, economical weapon is needed, e.g., the Mark 46 adapted for torpedo-tube launching. It is worth noting here that the Mark 48 torpedo is a general-purpose weapon and ideally fits neither the long- nor the short-range role.

Surface transits by diesel-electric submarines proved significantly harder to detect and classify than snorkel/battery transits. In areas where the transitor has control of the air—for example, near Soviet home ports—this tactic would be advantageous, for the U.S. Navy has at present no modern, effective weapon to use in attacking surface transitors. This situation is particularly worrisome because the Soviets' ECHO-class submarines launch their guided missiles when surfaced, at which time they could become critically important targets.

* * * * *

The Task Force has not examined the matter of torpedo countermeasures. This, in itself, is a subject of considerable scope, and attention to counter-countermeasures is vital to any weapons program. Thus, the subject is orthogonal to the foregoing recommendations.

3.1.4 Sonar: *Submarine-carried active sonar has been greatly "underplayed" in the Navy's planning for submarine warfare. The few exercise results available indicate that presently installed sonar is inadequate for search but is excellent for acquiring fire-control information.*

[redacted]

The use of active sonar for search, however, is problematical, but for some missions (area protection, for example) it may well be desirable. It is the power directivity of today's submarine sonar that makes it unsuitable for search. This limitation is not basic to active sonar.

3.2 [redacted]

4. EVALUATION OF EXERCISE RESULTS

4.1 General Comments on Submarine Exercises

The Task Force has examined the submarine exercises conducted by SUBDEVGRU TWO (New London, Connecticut) and, to less extent, those carried out by SUBPAC[4]. These exercises were conducted over the past 3 to 4 years as a part of the effort to evaluate the PERMIT class (SSN-594) in an antisubmarine role. The result is an impressive amount of data. Each engagement was carefully documented by at-sea measurements and other data, and this information has been stored in computer files for reference and study. In addition, SUBDEVGRU TWO has made a salutary effort to analyze these data and establish a basis for predicting the outcome of a U.S.—Soviet submarine engagement.

The Task Force admires the planning, skill and resolution that were evident in these trials. SUBDEVGRU TWO deserves an accolade for its work to gather and organize the exercise data. It was a task of massive proportions. About 5 to 10 percent of the available SSN services in the Atlantic was employed, and at times no less than six submarines, plus two ASRs (submarine rescue ships), were simultaneously involved. Thus, the data are well worth serious study.

In our interim report[5], we pointed out major questions concerning the ability of our SSNs to cope with large numbers of Soviet submarines in an undersea engagement. We called this the many-to-one problem and recommended that the Navy be requested to examine it further. At that time, there were some interesting data concerning the effectiveness of multiple coordinated submarines operating in an antisubmarine (SSK) role against a single boat. Since then, more data have been gathered, and a reasonable assessment can now be made.

The Task Force's concern extends beyond the many-to-one problem to the simpler one-to-one case, for an understanding of that interaction serves as a reference point. (The two cases are discussed in sections 4.3 and 4.4.)

Some long-standing beliefs concerning the SSK mission have been confirmed by the evaluations of both the Navy and the Task Force.

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[4]The results of SUBPAC (Submarine Forces, Pacific) trials are included in many of the tabulations reviewed by the Task Force. The one briefing on the Pacific trials that we received did not indicate that they differed significantly from the Atlantic exercises. We have not, however, reviewed the SUBPAC trials in detail.

[5]*Interim Report of DSB ASW Task Force* (Washington, D.C.: Office of the Director of Defense Research and Engineering, 1 July 1966), Secret.

First, an SSK's mission is basically to kill other submarines without itself being killed. (Since, in an SSK barrier, the transitor is to be destroyed, one measure of effectiveness is kill probability, which specifies the fraction of successful transits. On the other hand, in measuring effectiveness one must also consider the probability that the transitor may kill the SSK, which is the determining factor in attrition of SSK forces.) And, second, the effectiveness of a submarine in the antisubmarine role depends upon the following characteristics:

- Radiated noise level,
- Self-noise level,
- Sonar design parameters, including processing gain, array aperture gain, etc.,
- Mobility,
- Weapons effectiveness, and
- Other factors including the crew's morale and skill.

As far as the Task Force knows, these factors have not been synthesized into a figure of merit that would permit the direct comparison of, say, two submarines. Ideally, such a figure of merit would make it possible to predict both the kill probability for the SSK and the exchange ratio between SSK and transitors. The figure of merit, of course, would not be constant, but would vary with the submarine's operating condition. Though casting a wistful eye toward the goal of a meaningful figure of merit, the Task Force has not endeavored to formulate one.

The best that we have now is the conviction that, if a submarine has lower self and radiated noise, a higher performance sonar and greater mobility than an opposing submarine—and provided that its weapon is accurate and the crew skilled—it is extremely likely to win the engagement. Just how these factors trade off with each other and how they relate to kill probability and exchange ratio are not known. SUBDEVGRU TWO's data may enable an analyst to establish such a relationship, but this has not been formally attempted to the Task Force's knowledge. Fortunately, the exercise results yield some gross conclusions regarding tradeoffs.

After its evaluation, the Task Force is convinced that these general trends are correct—that is, low noise, high-performance sonar, mobility, etc., confer an advantage on the submarine so characterized. (Clear experimental evidence supporting this belief is presented in section 4.3.) In its interim report[6], the Task Force's recommendations on exercises concerned questions of how coordinated group tactics might alter this situation; that is, in terms of the earlier discussion, could they offset the SSK's higher figure of merit? This issue comes to the fore today because U.S. submarines of the PERMIT and STURGEON classes

[6] *Ibid.*

appear to have a clear figure-of-merit margin over their Soviet counterparts. Thus, the question becomes: How much of this advantage can be offset by the Soviets' coordinated use of large numbers of submarines?

4.2 Gathering and Analysis of Exercise Data

The Task Force has not examined in detail the raw data taken in these exercises. We have reviewed the techniques used to reconstruct the events at sea. The data are gathered manually at sea and are later manually processed to aid in reconstructing events of the exercise engagements.

We found that both the at-sea data recording and the reconstruction are done systematically. In any such process, errors will creep in, but there is no evidence of systematic error or bias that would invalidate the entire analysis. It is a burdensome task for the operators to manually record the data at sea, and at times this interferes with the exercise itself. Work on automated data recording is limited at present to the experimental installation of old equipment; no formal program is in progress.

SUBDEVGRU TWO's analysis resolves the reconstructed events into:

1. detection,
2. classification,
3. gaining attack position and firing,
4. assessment of attack accuracy, and
5. effect of weapon.

This resolution is useful, making it possible to compare corresponding parts of engagements that take place under different conditions. Ordinarily, however, SUBDEVGRU TWO presents this analysis only with regard to the SSK, not the transitor[7].

The results are then further condensed in the Group's analysis. Weapon-system effectiveness (WSE) is a product of ratios, that is, the relative frequency of events, as follows:

1. $\frac{\text{Number of detections}}{\text{Number of opportunities}} = P_D$

2. $\frac{\text{Number of correct classifications}}{\text{Number of detections}} = P_C$

[7]A similar resolution of intruder and trailing events into components is now being attempted; afterward, detailed analysis of exercises involving those units will be available.

3. $\frac{\text{Number of attacks made}}{\text{Number of correct classifications}} = P_{A_1}$

4. $\frac{\text{Number of accurate attacks}}{\text{Number of attacks made}} = P_{A_2}$

5. $\frac{\text{Number of kills}}{\text{Number of accurate attacks}} = P_K$

6. $\frac{\text{Number of accurate counterattacks}}{\text{Number of opportunities}} = P_{CK}$*

Note: *In the WSE product, $(1 - P_{CK})$ appears, not P_{CK}. Thus, WSE can be interpreted as the probability that the SSK will kill the transitor and survive the engagement.

The exchange ratio is merely the ratio of transitors killed to SSKs killed. Note that the WSE product, if quoted as a single number, can conceal important effects. For example, if P_K is doubled and P_C is reduced by one-half, the resultant WSE would be unchanged. Yet such shifts would be of vital importance in judging the relative effectiveness of the SSK in two different situations. Similarly, the exchange ratio as a bare number may hide significant effects. Thus, the Task Force prefers to consider the data in a less condensed form than weapon-system effectiveness and exchange ratio.

Though the amount of data in SUBDEVGRU TWO's archive is massive, most of it concerns the one-against-one conflict. The sample for other conditions is small (see section 4.4). For this reason, the Task Force prefers to look for gross effects in the data and to seek deterministic causes of those effects. This is the rationale on which we have based our assessment.

It is important, we feel, to point out that even the gross effects noted (in section 4.3) are subordinate to torpedo effectiveness. An accurate attack by an "undetectable" SSK can be vitiated by a malfunctioning torpedo that gives away the attacker's presence. Indeed, the exercise results have strong implications on the weapons side, as indicated in sections 3.1.3 and 4.4. Furthermore, SUBDEVGRU TWO points out that its exercises are relevant only up to the first shot. The melee that might ensue if the first shot does not end the engagement has not been investigated. The Group believes that this aspect cannot be realistically studied in exercises using "blank cartridges." The Task Force agrees with this conclusion. With today's—and perhaps tomorrow's—conventional weapons, second- and third-shot situations might be controlling.

4.3 One-vs.-One Exercises

In the majority of interactions in the SUBDEVGRU TWO and SUBPAC exercises, a single SSK intercepts a single transitor. To be specific, 521 in a total of 656 exercises have been of this sort. The data, including the ratios given in section 4.2, are shown in Table 1. Three different types of transiting targets were used:

(1) SEAWOLF, a noisy SSN,
(2) A diesel SS, and
(3) SKIPJACK, a quieter SSN.

[redacted]

Moreover, SKIPJACK, with its lower self noise, proved to be a much more dangerous opponent for the SSK than SEAWOLF. In 79 engagements, the SSK killed the transitor 14 times, while SKIPJACK killed the SSK 5 times. SEAWOLF was unable to kill the SSK even once in 111 encounters.

Because SKIPJACK, SEAWOLF and PERMIT are propelled by nuclear power, they are "single-mode" targets. (These submarines do not ordinarily operate on the surface when carrying out missions, so they are nearly true submersibles.) Diesel-electric submarines can operate in three modes—noisy, by snorkel; intermediate, on the surface; and quiet, on battery power. Although the diesel-electric (SS) targets' range and mobility are severely limited when they operate on batteries, the SSK was less effective against them than against SEAWOLF. The relative frequency of detection was .65 versus .86. The relative frequency of achieving an attack position was .64 versus .76, a difference that becomes significant when supplemented by comments of experienced Naval officers.

Compared to SKIPJACK, the SS was easier to detect (.65 versus .49) and harder to attack (.64 versus .79). The probable reason, according to experienced Naval officers, is that, on battery, the SS is more difficult to track and close. Also, the SS was not defenseless, killing

Table 1. SSN-594-CLASS SSK VS. ALL TRANSITORS, USING PASSIVE SONAR ONLY

	SSK vs. [Type of Transitor]		
Results	SEAWOLF SSN	Diesel SS	SKIPJACK SSN
Number of:			
Opportunities	111	178	79
Detections	96	115	39
Correct classifications	95	106	33
Attacks	72	68	25
Accurate attacks	49	42	14
Counterdetections	4	12	13
Counterattacks	2	10	9
Accurate Counterattacks	0	6	5
Ratios*:			
P_D	.86	.65	.49
P_C	.99	.92	.85
P_{A_1}	.76	.64	.76
P_{A_2}	.64	.62	.56
P_K (Using a single Mk 37-0)	.45	.65	.45
WSE	.19	.15	.08
Exchange ratio	Indeterminate	10:1	2.8:1

Note: *See section 4.2 for explanation of ratios.

Table 2. SSN-594-CLASS SSK VS. SINGLE AND DUAL TRANSITORS

Results	SSK vs. Single Transitor	SSK vs. Two Coordinated Transitors
Number of:		
Group transits	-	12
Opportunities	178	24
Detections	115	17
Correct classifications	106	16
Attacks	68	9
Accurate attacks	42	5
Counterdetections	12	6
Counterattacks	10	3
Accurate counterattacks	6	1
Ratios*:		
P_D	.65	.71
P_C	.92	.94
P_{A_1}	.64	.56
P_{A_2}, P_K	.40	.32
WSE	.15	.12
Exchange ratio	10:1	6:1

Note: *See section 4.2 for explanation of ratios.

Table 3. SSN-594-CLASS SSK VS. PAIRS AND GROUPS OF DIESEL INTRUDERS

Results	2 Intruders	4 Intruders	Totals
Number of:			
Group transits	15	5	20
Opportunities	30	19	49
Detections	21	7	28
Correct classifications	20	6	26
Attacks	16	4	20
Accurate attacks	8	4	12
Counterdetections	10	4	14
Counterattacks	9	4	13
Accurate counterattacks	7	2	9
Ratios*:			
P_D	.70	.37	.57
P_C	.95	.86	.93
P_{A_1}	.80	.67	.77
P_{A_2}	.50	1.00	.60
P_K (Using a single Mk 37-0)	.70	.70	.70
WSE	.15	.13	.14
Exchange ratio	1.1:1	2:1	1.3:1

Note: *See section 4.2 for explanation of ratios.

the SSK in 6 engagements and being killed in 42 (assuming no differential in weapon effectiveness) out of 178 cases. The conclusion is that a quiet mode of operation, if used judiciously, can considerably increase the effectiveness of a noisy submarine. (On snorkel, the SS was 5 to 7 decibels noisier than SEAWOLF and so would be more vulnerable if it snorkeled continuously.)

To transit an SSN barrier with the least risk (assuming that friendly air cover is available), a single SS should move on the surface at high speed. Of the 40 or more surface transits by diesel-electric submarines, only about 25 percent were detected, compared to at least 75 percent detected on snorkel/battery transits. Also, of all the targets in these exercises, those on the surface proved to be the hardest to classify correctly. This result points strongly to a pressing need for a modern torpedo effective against surface targets.

4.4 Exercises Involving Multiple Transitors and Intruders

At least four different paradigms of multiple submarines transiting and lying in wait for the SSK have been investigated by SUBDEVGRU TWO. In total, there have been some 95 interactions of this type. Though they are expensive in precious submarine time and there is always the danger of collision, the data they provide are of great value. The participating ships are to be complimented on their skill in carrying out the necessary maneuvers, and the members of SUBDEVGRU TWO deserve commendation for their imaginative approach.

Nevertheless, in examining the results of these trials, we must keep in mind that the data base is understandably small. Thus, "averages" are not necessarily typical, and differences in performance values must be large to be significant. Particularly, if results are to be relevant to a range of conditions, it is vital to uncover the deterministic factors.

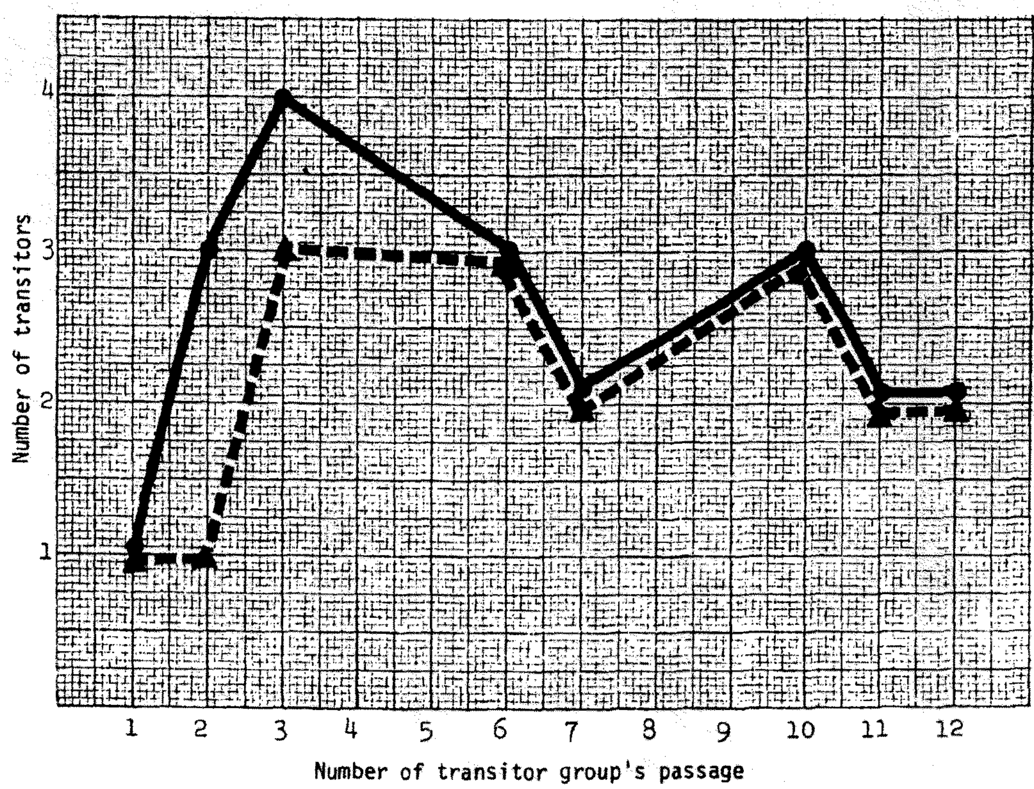
In Table 2, SSK performance vs. pairs of submarines is compared with typical one-to-one engagements. Perhaps the salient feature is that the bare numbers on detection, classification, etc.—specifically, WSE (weapon-system effectiveness) and exchange ratio—do not differ greatly from those of the one-to-one situation. In two particularly interesting exercises, however, as shown in Table 3, there was a striking difference between the one-to-one results and the SSK vs. a pair of diesel-electric submarines and four transiting in a group. As indicated by results of 20 engagements, the transitors and the SSKs would achieve about the same number of kills. In all subsequent trials, in some of which torpedoes with dummy warheads were fired actually to hit the target, the SSs did not do as well (see Table 2).

The difference between these two sets of results appears to arise from the fact that the AN/BQR-2B sonar carried by the SSs is more sensitive to bathymetric conditions than the PERMIT class's AN/BQQ-2. Under

Figure 1. USS DACE VS. GROUP OF FOUR TRANSITORS

Legend:

Number of transitors detected.
Number of transitors attacked.



poor conditions the BQQ-2 aboard a PERMIT far outperforms the BQR-2B on a battery-powered SS, while under some unusual conditions they may perform about equally. The data in Table 3 reflect the latter situation. Further information on these trials indicates that the PERMIT submarine and a battery-operated SS can detect each other at about the same range, 15,000 yards. Under this circumstances, the engagement is almost a standoff. In subsequent exercises, as indicated in Table 2, the detection performance of SSs was much poorer than that of PERMITs.

It appears that this is the most striking effect uncovered in the multiple-intruder exercises. That is, the figure of merit for SSs and noisy nuclear-powered submarines in the group transits was ordinarily so inferior to that of the SSK that all the benefits (if any) of massing and coordination in the engagement were masked by this gross difference. In the Task Force's estimation, this is a key conclusion in its interpretation of exercise results.

A smaller effect showing up in the data tends to confirm this viewpoint; that is, massing noisy, slow boats against quieter, more mobile SSKs results in greater SSK effectiveness in terms of the percentage of possible targets killed. Figure 1 illustrates this point: Four SS transitors were pitted against two SSKs operating singly in different areas. After a bit of experience, each SSK killed at least two SSs on each pass of the group, or 50 percent, as compared with an approximately 25-percent kill against a single SS transitor.

This same effect was shown in still another exercise in which the transiting SS or SEAWOLF was escorted by surface ships (DD or DE). Again, the amount of data is small but the effect is clear (see Table 4). With escort, about half of the transits were successfully intercepted; without escort, only a quarter. According to Naval officers, the noisiness and prominence of the escort provided a focus for the SSK's activity. The escorts, themselves, proved ineffective in the submarine-vs.-submarine engagement.

The Task Force therefore concludes that, in most of the many-vs.-one exercises, the opponents were so mismatched that the influence of any tactics is masked. The relatively small amount of data does not permit separating these effects. Overstating the case to clarify the point, many "deaf" transiting submarines cannot defend themselves no matter what tactics they employ. Massing them merely gives the SSK a concentration of accessible targets. Clearly, in order to isolate the effect of tactics, it would be most economical of submarine time to use as adversaries submarines whose capabilities, or figures of merit, are comparable.

Some caveats should be stated along with the foregoing conclusion. Though SUBDEVGRU TWO has been imaginative with respect to tactics employed in exercises, they have not explored all promising possibilities, for example, decoys and "foxers." *More important, it seems that a likely*

Table 4. EFFECT OF TRANSITORS' ESCORT BY SURFACE SHIPS
(SUBASWEX 4-64 and 1-65)

Results	Escorted		Unescorted	
	Diesel SS	SEAWOLF	Diesel SS	SEAWOLF
Number of:				
Transits	12	6	14	26
Accurate attacks by SSK	5	3	4	7
Percentage of:				
Transitors accurately attacked	41.6%	50%	28.5%	26.9%
Total transitors accurately attacked	44.4%		27.5%	

NAVY 3.3(b)(1),(4)

OSD 3.3(b)(1),(4)

Table 5. SSK VS. SSN AND DIESEL TRANSITORS, USING ACTIVE SONAR

[redacted]

Soviet tactic, particularly in the first deployment phase of a war, would be to saturate an SSK barrier area by a mass transit of, say, 50 submarines. Needless to say, the U.S. Navy has not tried such massive movements at sea because of the time and resources involved. For illustration, assume that the enemy attempts a mass transit of 200 submarines. If we assume that, for each engagement of an SSK and a transitor, the probabilities are 0.20 that the transitor will be killed and 0.05 that the SSK will be killed, and if we also assume that after the SSK is destroyed the remaining transitors will take advantage of the hole created in the barrier, then there would be a 0.92 probability that only 10 of the 200 transiting submarines will be killed at the barrier.

Thus, even though U.S. submarines have a large advantage per unit, their Soviet counterparts might use saturation tactics to offset it—at least, in the beginning[8].

4.5 Use of Active Sonar

OSD 3.3(b)(1),(4) NAVY 3.3(1),(4)

In a few experiments, the PERMIT-class SSK used active sonar both to search and to attack the transitor, with the results shown in Table 5. Several interesting features are evident. The slower, less maneuverable SS is detected in more cases than a PERMIT-class transitor, probably owing to the latter's greater mobility. This advantage is exaggerated in these exercises because the active sonar used by the SSK is not designed for search; it has only a narrow-beam capability because of power limitations and takes some 45 minutes to search all around.

[redacted]

This brief trial reinforced existing ideas, namely, that active sonar is well suited for detecting low-noise targets and for obtaining accurate fire-control data at standoff range. On the other hand, active sonar reveals the presence of its platform.

In spite of their interesting results, these exercises could have been much more imaginatively designed. For example, they might have investigated ranges at which fire-control data can be obtained and the resulting kill probabilities and exchange ratios. The Task Force believes that such trials would reveal the need for new long-range weapons and new tactics as well. Both might be of great value to an SSK confronted by a large number of noisy adversaries.

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[8]NEWCLOPS simulations support this conclusion.

OSD 3.3(b)(1),(4) NAVY 3.3(b)(1),(4)

Table 6. REPRESENTATIVE DETECTION AND CLASSIFICATION RANGES: SSK VS. VARIOUS TRANSITORS

[redacted]

4.6 Torpedo Firings

Naval officers participating in the exercises reviewed by the Task Force unanimously agree that operational attitudes and actions are influenced to a major degree by a "hit-shot" situation, in which torpedoes are fired to impact on target. Yet we were hard pressed to find any reflection of this influence in the numerical accounting of detections and attacks[9]. We therefore concentrated on examining each torpedo firing as a test of the weapon itself.

In summary, the Mark 37-1 torpedo is not a star performer. In one exercise, it did not function in 16 out of 24 attempted firings. In later trials, 10 out of 11 operated, but 5 were detected and evaded by SKIPJACK, the target. In another instance, there were 7 hits out of 40 attempted launchings; about 28 failed to perform satisfactorily because of either malfunctions or design limitations. SUBDEVGRU TWO has modified the Mark 37-1 to avoid surface capture in its active mode, and this has improved the performance somewhat. The Mark 37-2 modification promises further improvements. Even with these additions, though, the Mark 37 is an unsatisfactory weapon in many situations, particularly against shallow noncavitating targets. Officers say they would not try to fire the Mark 37 outside a range of 8,000 yards, and they would prefer to be within 3,000 to 4,000 yards. Thus, it must be viewed as a short-range weapon.

The Task Force considers the torpedo problem one of the most critical facing the submarine force. We look hopefully toward the Mark 48 development program, but exercise results point to the need for additional new weapons to take advantage of the long ranges at which noisy submarines can be detected. Table 6 compares detection and counterdetection ranges for a PERMIT-class SSK against various targets.

In all the exercises, there is no case of a transitor's detecting an SSK before being detected itself; all counterdetections occurred during the SSK's attack. It is clear that the risk of counterdetection (and counterattack) could be reduced essentially to zero if the SSK were able to attack from a distance greater than 20,000 yards. This would, for example, reduce the effectiveness of SKIPJACK-type transitors—30-knot submarines that are quieter than the "noisy nuclear" SEAWOLF—offsetting their speed advantage and lessening their ability to counterattack.

With a standoff weapon, an SSK would have greater target-handling capacity. Exercise results show that the time from first detection by an SSK to (Mark 37) torpedo launch is typically measured in hours—up to 8 hours against an intermittent snorkeler. Much of this time is used in closing the target to within firing range, 3,000 yards or less. With a long-range weapon at its disposal, the SSK could close and attack its target in a much shorter time.

[9]One effect noted was that firing range was generally shorter when the torpedo was fired to hit the target.

OSD 3.3(b)(2),(4)

Evidently, from the detection and classification ranges in SUBDEVGRU TWO's exercises, a weapon that can be used out to the first convergence zone (60 to 65 kiloyards) would be useful. A SUBROC vehicle with a conventional homing warhead would be such a weapon. [redacted] The Task Force understands that a study of a conventional SUBROC, based on an unsolicited proposal, is in process.

A long-range weapon's fire can be controlled either by active sonar or by improved passive ranging (a multiple-bearing method, not PUFFS). Present techniques of passive ranging are only about 20-percent accurate, which is not good enough for a SUBROC/Mark-46-type weapon. [redacted] SUBDEVGRU TWO is studying new techniques that may improve this figure somewhat.

In any case, passive ranging will be necessary as a preliminary to the selective use of active sonar. Passive search should tell enough about the target's position that the SSK can assess the probability of a return from a single ping or from several. When the probability is high enough, the active sonar can be brought into use, shortly before firing.

Tactics based on these ideas could make a conventional standoff weapon an important addition to the submarine force's arsenal.

There is need, too, for an economical short-range torpedo such as the Mark 46. Undoubtedly, close-in situations will occur in which such a weapon would be very effective.

NAVY 3.3(b)(1),(4)

4.7 Trailing Exercises

[redacted]

OSD 3.3(b)(1),(4)

NAVY 3.3(b)(1),(4) OSD 3.3(b)(1),(4) ~~SECRET~~

[redacted]

4.8 Simulation and Computing Facilities

Simulation of at-sea exercises is an attractive alternative to actual exercises, which are expensive and burdensome to carry out. If properly done, simulation can reduce at-sea time and sharpen the issues to be resolved. An adequate simulation model would establish relationships between measurable characteristics of the submarine—such as self and radiated noise and sonar gain—and its exercise performance in terms of detections, attacks, kills, etc.

Only when these relationships are understood will it be possible to answer tradeoff questions concerning noise reduction, sonar performance, mobility and the like—for example: How would the effectiveness of PERMIT-class SSKs be affected if diesel-electric transitors were to acquire a sonar capability similar to that of the AN/BQQ-2? Answers to such "sensitivity" questions are vital in determining how rugged the SSK's effectiveness is.

SUBDEVGRU TWO has contracted with the Electric Boat Company for a simulation model that can be used in some of these determinations. This contract is producing interesting results and is not at present limited with respect to funding. The Task Force understands that the Office of the Assistant Secretary of Defense (Systems Analysis) has a more extensive model under development. We have not examined that model. Additional efforts in this area, however, seem unwarranted at this time.

Any simulation model is of little interest to SUBDEVGRU TWO today because of the inadequacy of available computing facilities. The New London Submarine Base has a Honeywell 800 machine that it uses for training and logistics support. The Group has used this machine also for data storage and a few other applications. A major expansion of these facilities is necessary if they are to serve the Group as an effective aid in planning and analyzing their exercises and other activities. A recent study by the Group established a realistic set of requirements[10], on which proper action should be taken.

The NEWCLOPS simulations are war games carried out at the Naval War College, Newport, Rhode Island, with the participation of Naval officers enrolled in the college. These simulations are different from those mentioned above, and are valuable in investigating such issues as re-attack strategy and the effectiveness of saturation tactics. The Task Force believes that such war games offer a good deal of insight and valuable training, but the fact that life and limb are not at stake detracts from their realism.

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[10] "COMSUBDEVGRU TWO Computer Facility Requirements," letter dated 8 February 1968 to Chief of Naval Operations (OP-31) from Commander Submarine Force, U.S. Atlantic Fleet.

~~SECRET~~

ABBREVIATIONS

ASW -- antisubmarine warfare

CEP -- circular error probable

DSB -- Defense Science Board

SSK -- antisubmarine submarine

SUBDEVGRU -- Submarine Development Group

SUBPAC -- Submarine Forces, Pacific

WSE -- weapon-system effectiveness

(The material on this page is unclassified.)