(1) 11-M-1228

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The Dept of the Navy, Sean L. Carney, DUSN PPOI/SD completed MDR on 7 Feb 2014. Information has been redacted IAW DON SCG 05-037.2 OR SCG 05-038.3 (1)

SUBMARINE NOISE LEVELS (U)

Report of the
Defense Science Board ASW Task Force

Office of the Secretary of Defense 5 U.S.C. § 552
Chief, RDD, ESD, WHS
Date: 28 FEB 2014 Authority: EO 13526
Declassify: ______ Deny in Full: ______
Declassify in Part: X
Reason: 3.3(b)(1)(4)
MDR: 11 -M- 1228

25 June 1968

[redacted]

Office of the Director of Defense Research and Engineering
Washington, D.C. 20301

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Authority: EO 13526
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OFFICE OF THE DIRECTOR OF DEFENSE RESEARCH AND ENGINEERING
WASHINGTON, D. C. 20301

2 July 1968

MEMORANDUM FOR THE SECRETARY OF DEFENSE

THROUGH: THE DIRECTOR OF DEFENSE RESEARCH AND ENGINEERING

This is the third and final report of the Defense Science Board's Task Force on Antisubmarine Warfare. It is concerned with reducing the noise level of existing and future submarines. The previous two reports dealt with fixed sonar arrays and with submarine-to-submarine exercises and engagements. The three reports together complete the survey undertaken by the task force at the request of Dr. Foster.

The Defense Science Board has given its general endorsement to this report, and we recommend it to your attention. The Board wishes to emphasize the prime importance of noise level reduction as a means of improving submarine effectiveness. The report contains specific suggestions on how this quieting can be accomplished.

Robert L. Sproull

Robert L. Sproull
Chairman
Defense Science Board

[redacted]

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

24 June 1968

MEMORANDUM FOR CHAIRMAN, DEFENSE SCIENCE BOARD

SUBJECT: Submarine Noise Levels: Report of the Defense Science Board ASW Task Force

The DSB ASW Task Force herewith submits its final report on Submarine Noise Levels.

In summary, the Task Force believes that there are a number of measures which can be applied to quiet submarines. The most basic of these measures is standardization of design and construction aimed at achieving uniformly quiet submarines. Recommendations 1 and 2 concern this matter. The Task Force believes that there are well known noise-reduction techniques which would, with proper controls, reduce today's lowest noise submarine by perhaps 2 to 4 db in some frequency ranges. Recommendations 3 and 4 concern fitting these features into present and future submarines. To assist in achieving such results, new measurement techniques will be required, as recommended in 5.

The Task Force found that only a beginning has been made in measuring and silencing transient noises. This work should be accelerated and refined as indicated in Recommendation 6. R&D generally has been subordinated to fixing today's problems. Recommendation 7 addresses this situation. Management of the NavShips program office is the subject of Recommendation 8.

The Task Force has not been able to establish an order or priority for these recommendations. All are urgent and should be the subject of action. The members of the Task Force will be happy to consult with ODDR&E to facilitate implementation of these recommendations.

E. E. David Jr.
Edward E. David, Jr.
Chairman
ASW Task Force

[redacted]

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THE TASK

The task assigned to the Defense Science Board's ASW Task Force by the Director of Defense Research and Engineering (DDR&E) is as follows:

> The superiority of our nuclear submarines vis-à-vis the Soviets' is due in considerable part to the fact that ours are relatively quiet while theirs are relatively noisy. It is important that this element of relative superiority be retained throughout the foreseeable future, and we are supporting RDT&E effort to achieve this goal. However, we need additional assurance that this effort is sufficient, timely, and well directed enough to meet that goal.
>
> I would like the Board to examine this total field, including: (a) implications of achieving various levels of self and radiated noise, including steady state noise such as that associated with propulsion machinery and transient noise such as that associated with the launch of a torpedo; (b) adequacy of techniques for measuring noise; (c) adequacy of techniques of modeling the noise-related design features of submarines for the purpose of predicting noise levels prior to construction and test of the submarine; (d) relation of the availability of specialized production and maintenance facilities and techniques to problems of noise control; and (e) the possibility of utilizing new methods of propulsion to achieve quieter submarines.
>
> This is a problem of continuing importance and therefore not one on which a firm study completion date need be established now. However, progress reports should be submitted no less often than every three months; and, to insure that work proceeds toward some agreed-on goal, I request that a November 1, 1967, target date be set for study completion.

INTRODUCTION

The ASW Task Force was assigned a subtask—to investigate the research, development, test and evaluation (RDT&E) effort required to ensure that present U.S. superiority over the Soviets in submarine noise levels be maintained in the future. The DDR&E desired us to obtain assurance that the submarine noise-reduction effort is sufficient, timely and well directed to meet the goal of maintaining our superiority.

The Task Force was asked to examine the total field from the point of view of transient as well as sustained noise levels and to look at the possibility of using new methods of propulsion to achieve quieter submarines. In addition, we were to check on noise-measuring techniques and on the adequacy of techniques for modeling noise of machinery for purposes of predicting noise levels prior to the construction and test of a submarine. Further, the availability of adequate facilities and techniques for noise control was to be determined.

The assignment of the task was undoubtedly based on the assumption that the state of the art relating to submarine noise levels had reached a plateau and that it was imperative to ensure that current programs are adequate to keep U.S. submarines continually ahead of the Soviets'.

Before undertaking to assess the specific points set forth in the subtask, the Task Force conducted a general review of the field to ensure that any evaluation we made would take into account the actual status of the submarine-silencing program.

The Task Force felt it worthwhile to review not only the current status of noise-reduction practice (see section 2) but the events leading up to the present generally unsatisfactory situation. It was clear that the undertaking of new programs would be premature if problems we have now cannot be solved. Our review of submarine noise-reduction efforts since World War II is presented in Appendix A.

1. RECOMMENDATIONS AND CONCLUSIONS

Most U.S. submarines today are significantly noisier than they need to be. Present policies and planning relative to submarine construction are liable to worsen the situation. Current research and development activities are not likely to produce any major innovation that will yield a new technology for noise reduction. R&D people are heavily engaged in correcting existing shipboard installations. There is not enough talent to develop design standards and analytical tools to achieve consistent or improved results in noise reduction. Furthermore, procurement policies and construction practices make it difficult to incorporate advances routinely and effectively into new submarines.

The Task Force concludes that radical changes are required if quieter submarines are to be obtained. Our recommendations for a beginning are as follows:

1. Construction of each class of submarines should be standardized so that identical components, systems and installation procedures are used in members of a class.

[redacted]

The major contributor to this noise problem in new construction is the lack of standardization. This situation can be remedied only if all ships in a class are built to the same class plans (which, of course, should be modified as new knowledge and techniques make it advisable), even if they are not constructed in the same yard. Only in this way can the multitude of design variations be reduced to attack the noise problem effectively.

[redacted]

2. Immediate steps should be taken (probably through an outside contractor) to compile design standards, empirical data and analytical tools that will serve as a specific technological base for the work of submarine designers and construction engineers.

At present, the quietest submarines are achieved only through the personal and aggressive intervention of commanding officers during construction. Thus the noise program today relies primarily upon individual personalities rather than a prescribed routine. Furthermore, the experience gained and the techniques developed—comprising today's state of the art—reside in the heads of a selective few people. This state of the art is not routinely incorporated in subsequent construction. Before it can be applied, this knowledge and technique must be documented in such a form that they can be used as a base for further progress and for establishing realistic noise specifications.

An aggressive effort is needed to apply existing knowledge in a consistent way and to identify areas of missing fundamental knowledge for further research.

[redacted]

3. A major effort involving additional time and money is essential to ensure that the state of the art, as represented by the *USS Ray*, SS(N)653, is incorporated into submarines now in the construction "pipeline." Moreover, if quietness is to be supported as a prime requirement, additional time and funds must be scheduled for both construction and overhaul to allow repeated cycles of measurement and correction. Thus, achieving quieter submarines necessarily implies either fewer boats on the line or higher total force levels.

[redacted]

Despite naval doctrine that noise is a prime determiner of submarine effectiveness, the Navy's noise program is, in fact, of low priority. Both shipyards and operators are reluctant to schedule adequate funds and time for noise-correction work or for test time. Quietness is today considered a secondary characteristic that is frequently abandoned under the pressure of cost and schedule.

4. Advanced noise-reduction steps should be backfitted into one representative submarine from each of the SS(N)585, SS(N)594 and SS(N)637 Classes as a trial program to assess the cost and effectiveness of a noise-improvement program for existing forces.

Some backfitting for noise reduction in existing ships is being undertaken on a piecemeal basis. There is, however, no program aimed at factoring known improvements into all commissioned ships. The Task Force was unable to assess the cost and effectiveness of such a program but believes that a trial program is justified. The most advanced noise-reduction techniques should be fitted into three of the Navy's modern submarines, within their present physical limits, to determine the comprehensive program's cost and effectiveness. To minimize down time and cost, this should be done concurrently with a regularly scheduled overhaul. It is also important that the requisite test and evaluation time be factored into the trial program.

5. Special measurement techniques should be developed so that the noise performance of submarines can be determined easily and often. [redacted]

6. Work in the area of transient noises should be included in all aspects of the noise-reduction program. Of special concern is the need for measurement techniques that quantify transient noise to assess the effectiveness of silencing measures.

[redacted]

7. Steps should be taken to encourage submarine construction shipyards and the component industries to develop R&D and design strength in the noise-reduction field. Perhaps the most effective step would be to assure a continuing program of new construction. Stable funding of R&D related to noise reduction is a necessary concomitant, both outside and inside the Navy.

At present, the R&D program in noise reduction and low-noise design capability is talent limited. The ability required is highly specialized, and it is hard to attract qualified people into Navy laboratory programs. The supply of appropriate people in the country is probably adequate, but they must be trained and educated in the concerned laboratories with a view to the specific needs of the noise-reduction program. To cure the shortage, stable funding with selective growth should become the policy. This policy is not being followed today.

Laboratory personnel are today heavily engaged in correcting existing shipboard installations. Also hampered by funding fluctuations, the R&D program has not grown to meet its expanding responsibilities. Because of this situation, there is little or no effort to develop design standards and analytical techniques or to explore entirely new noise-reduction concepts aimed at producing a major change in the state of the art. [redacted] Greater emphasis should be placed on those aspects of the noise-reduction problem.

NAVY 3.3(b)(1)(4)

OSD 3.3(b)(1)(4)

In the area of design standards and analytical techniques, improved methods should be developed for measuring and isolating principal sources of radiated and self noise and correlating machinery vibrations to such noise.

Theoretical understanding of noise-producing mechanisms is not adequate to predict the performance of submarines from their design or to compare alternative designs. The Task Force recommends a continuing program of research aimed at prediction of noise levels from the design parameters of the submarines, including both theoretical and model studies.

[redacted]

8. The office of the NavShips noise program manager should be strengthened by the addition of at least 10 qualified engineers, and the manager should be at the level of Captain. (At present, the manager's billet calls for a Commander with a staff of five.)

The Task Force notes a growing interest in reduction of surface-ship noise. Considering the shortage of personnel, the Task Force recommends that qualified people not be diverted from the submarine program. Any surface-ship program should rely upon newly acquired resources.

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

[redacted]

2. PRESENT STATUS OF NOISE-REDUCTION PRACTICE

The state of the art of reducing submarine noise is largely empirical and is not adequate to achieve the Navy's stated goals for radiated and self noise. [redacted]

The Task Force finds that the RDT&E program is limited more in talent than in finances. Of course, recent RDT&E budget cuts may change this conclusion. The talent for a much expanded program is not available on a short time scale. What is required is strong direction of the present effort to consolidate the existing technology and incorporate it into the ships and strong coupling between research and design and construction. The Task Force recommends a resolute effort to integrate the noise-reduction program, from RDT&E through construction, testing and ships' trials.

In the following discussion, it is convenient to divide noise sources into the categories of hull flow, propeller and machinery noise.

2.1 Primary Noise Sources

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

[redacted] These are all steps in the right direction, but progress is slow.

[redacted]

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

[redacted]

2.2 Deficiencies in the Program

[redacted]

NAVY 3.3(b)(1)(4)

The fact that design data and procedures are not available to permit a definition of the state of the art has not only limited the capability to specify noise requirements but has also resulted in a different "state of the art" in each yard—and in each shop within each yard. It is generally recognized that *noise design criteria* in most areas are not available to enable the designer to make decisions that are essential to designing "quiet" into the ships. This fact contributes to the erratic noise performance from ship to ship. Some work is under way on the preparation of design criteria, but its completion is over a year away.

The *testing program* is not structured to provide the noise criteria the designers need. The bulk of the noise testing effort is expended in determining the noise characteristics of ships. Voluminous structure-borne, radiated and self noise data are taken during underway tests and in addition to the extensive component vibration testing and overside noise surveys. Test results are used in trying to identify the sources and transmission paths of particularly bad peaks in the ship's noise spectrum. Then, those sources and transmission paths are treated. Usually a number of possible "fixes" are applied simultaneously for schedular reasons. As a result, it is not always possible to know which of the fixes contributed to the consequent noise reduction.

There is no carefully prepared test program incorporating properly formulated test procedures and a complete data evaluation specifically aimed at establishing a better design basis. More "controlled" shipboard tests to evaluate modifications are required. A coherent, well-coordinated program involving government laboratories, shipyards and the Submarine Force is essential to redirect engineering and test efforts toward obtaining badly needed workaday design data and methods. Availability of submarines for noise testing and evaluation has been severely limited; postoverhaul, overside noise tests to measure the effectiveness of component repair and design changes made during the overhaul are often canceled for schedular reasons.

2.3 Other Mechanical Noise Sources

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

To give some feeling for the state of the art, some examples of current system noise conditions are described in the following paragraphs.

[redacted]

Pumps still represent an important class of the identified noise offenders. [redacted]

NAVY 3.3(b)(1)(4)

[redacted] The designer does not have answers to such questions as: How much will the ship's noise characteristic be affected by the type of pump, pump clearances, bearing noise, impeller type, etc.? In addition, there has been some progress in reducing pumping pulsations by the development of multivane impellers. Action taken to apply the results of this work, however, has been inadequate.

[redacted] There has been little incentive for companies to maintain the highly technical staffs necessary to make progress in this field, as the Navy work represents so small a fraction of total business. The little technical talent they have is held back; they prefer to use it on commercially profitable business. Unless some financial incentive for equipment suppliers can be developed, the Navy may be forced to develop this competence at its own (or other) development centers.

2.4 System Fluid Flow Noise

Steam or other piping fluid flow is a source of white and resonant radiated and self noise. Specific noise sources of this type are relatively hard to identify, because the observed frequencies do not necessarily correspond to any easily isolated system characteristic, such as pump rpm. It is known that fluid-flow noise is a major offender, yet we do not know enough about the details of its generation and transmission or how it affects overall ship's noise.

A few design practices based on qualitative experience have been developed, but system designers are largely working in the dark. Many fundamental design questions remain. It is not known, for example, what the relationship is between fluid velocity and radiated noise, or how much difference there is in noise resulting from flow through various types of valves, orifices, heat exchangers and other system components. [redacted]

2.5 Noise-Transmission Paths

[redacted]

NAVY 3.3(b)(1)(4)

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

[redacted]

2.6 Transient Noise

[redacted]

2.7 Program Management   OSD 3.3(b)(1),(4)   NAVY 3.3(b)(1)(4)

The administration and direction of the submarine noise-reduction program is under a program officer (Commander billet) who reports to the submarine acquisition manager in the Naval Ship Systems Command. The program officer is assisted by five civilians. Although this small group is responsible for administering a $10-million development program, nearly all of their time is devoted to daily "fire drills" relating to individual ship problems rather than overall program administration.

They have a broad charter in submarine noise reduction, but their efforts are hampered by the lack of priority and subsequent ship test time, insufficient contract leverage with manufacturers and shipbuilders, and the lack of programed funds for ship corrective action.

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

3. SUBMARINE NOISE SPECIFICATIONS AND ACTUAL NOISE LEVELS

[redacted]

The specifications for the FY 1967-68 procurement of new SS(N)637 Class submarines have been revised to include a noise review program, in which each shipbuilder and design agent review noise-critical areas and define the improvements that will be made. The success of this approach will depend on the thoroughness and vigor of the Navy in assuring its implementation.

The following paragraphs describe how specifications and performance vary between classes of ships. Actual radiated- and self-noise performance is also included.

[redacted]

Table I. COMPARISON OF SPECIFICATION AND CLASS AVERAGE RADIATED-NOISE LEVELS

[redacted]

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

[redacted]

Prior to 1964, the radiated-noise specification did not change to any great extent, yet the ship's radiated-noise levels varied widely and were well above their specification. The SS(N)594 Class averages showed improvement, but subsequent classes of ships have been worse in this regard. The SS(N)653 data indicate that significantly better results can be achieved when the present technology is more fully applied.

Since the entire program was run on the basis of no interference with schedules and "best efforts" on the part of individual shipyards, the results have varied greatly among ships. In fact, the difference in noise levels of any group of ships produced within a particular time span varied far more than the overall trend from 1961 to 1967. This also applies in the most recent class of SSB(N)s, the SSB(N)640, in which all the latest acoustic techniques were to have been applied. Table II demonstrates the variability among the ships of the latest class of SSB(N)s.

[redacted]

Table II. COMPARISON OF RADIATED-NOISE LEVELS OF SSB(N)640 CLASS

[redacted]

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

Table III. COMPARISON OF SPECIFICATION AND CLASS AVERAGE SELF NOISE
Ship Speed of 4 to 5 Knots

[redacted]

Table III shows class average self noise and how it compares with the specification levels in the frequency band of major concern. In addition, the levels achieved on the SS(N)653 after alterations are shown, as in Table II on radiated noise.

The self-noise specifications have changed from class to class, and ship noise levels have been well above the specifications. SS(N)594 Class ships were worse than the SS(N)588 Class, and subsequent ship classes show a wide variation. The SS(N)653 ship, after alterations, was about the same as the SS(N)588 Class.

4. TECHNIQUES OF NOISE MEASUREMENT

In many ways, noise-measurement techniques are adequate for purposes of RDT&E as well as at-sea trials. While at present they serve to localize noise sources to the extent of identifying the offending system, they are often inadequate for the analysis and identification of the system's noise-producing elements. The noise mechanism is frequently a product of the assemblage of components and cannot be attributed to any one. There is no satisfactory theoretical model with which to treat such cases, either for initial design or backfit.

The Task Force concludes that apparent discrepancies in measurements made by different techniques (which have been a subject of controversy) can be reconciled by proper calibration and data processing. [redacted]

The Task Force recommends the continued development of measurement techniques, with emphasis in the following areas:

(1) Measurements in conjunction with analytical models to permit identification and elimination of noise sources;

(2) [redacted]

(3) Techniques for measuring transient noise and for assessing the effectiveness of silencing measures.

4.1 Comparison of Noise Measurements:

[redacted]

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

[redacted]

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

4.2 Comparison of Noise Measurements: Acoustic Range and Mobile Platform

A limited amount of data has been accumulated during the past year on measurement of targets' acoustic levels by mobile instrumentation. The mobile platform consists of a submarine with an accurately calibrated passive sonar array, supplemented by appropriate electronic instrumentation to enable reliable magnetic-tape recording of the array output. Numerous measurements from a mobile platform have been made, three of which are described in the following paragraphs and compared to measurements made at a sonar range.

[redacted]

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

It should be noted that the measurements on both *Trumpetfish* and *Tench* were made by civilian personnel from different laboratories, while the *Tinosa* measurements were by military personnel with little specialized training for this purpose.

5. PREDICTING RADIATED AND SELF NOISE

Techniques of predicting radiated and self noise of submarines from their designs are largely inadequate, and they are also inadequate for comparing alternative designs. This is primarily the result of the complexity of noise-transmission paths—piping, cabling, foundation structure, hull structure, fluid in piping systems, and air. The noise sources are also complex combinations of many hard-to-define variables. It is extremely difficult to realistically model sources and paths of submarine noise.

Some attempts have been made to develop methods of predicting self and radiated noise. These methods fall into two classes—those that are derived from correlation of ship tests and those derived from first principles. In the first instance, the methods are only useful in evaluating small departures from designs for which there is a large body of test data. The second group, consisting of theoretical calculations, usually falls short of an ability to define boundary conditions that bear an accurate relationship to the real world or to describe adequately the mutual interaction of the many complex elements of the system.

While the Task Force recognizes the great difficulty in developing adequate prediction methods, we believe that some continuing effort should be expended in the pursuit of such techniques.

APPENDIX A

A Review of Submarine Noise Reduction Since World War II

1. Before *Thresher*

There has been a definite effort to reduce submarine noise since early in World War II when it was discovered that the gear-drive electric propulsion motors in our submarines were far too noisy. One of the big developments during World War II was the slow-speed direct-drive motors, which were backfitted into all operating submarines and became the standard for new-construction diesel-electric submarines. Other techniques that were available were the rubber-mounting of components that could not be safely secured under conditions of silent running and the balancing and careful selection of bearings for motor-driven components.

Thus, when the plans for *Nautilus* were being developed in 1950, basically the only available techniques for noise reduction were those that had been developed during World War II. Although primary emphasis was given to the development of a reliable nuclear propulsion plant, noise reduction was not ignored in *Nautilus*. [redacted]

[redacted]

2. *Thresher* Class

[redacted] As of the writing of this report, no detailed noise evaluation report of that particular drive is available.

[redacted]

[redacted]

The noise specifications that were set down for all the components in *Thresher* were basically targets, for the state of the art was not at a point where manufacturers were willing to provide guarantees. In fact, the noise spectrum of each of the components was negotiated case by case. Where vendors had noise problems in a particular frequency band, they would ask for a relaxation in that band before they would accept the order. Most of the contracts for the components were, in essence, on a "best-effort" basis. Many of the components were shipped before the targets were reached, because the vendors felt they had done the most they could for the dollars that were being expended and further results would not be forthcoming within the existing technology.

[redacted] A large amount of effort has gone into the solution of this problem on subsequent submarines.

3. After *Thresher*

The post-*Thresher* period, 1961 to the present, was characterized by the most intensive submarine construction in this country since World War II. In addition to the follow-on *Thresher* attack submarines, a new class of attack submarines, *Sturgeon*, was begun. Delivery of the initial ships of this class has commenced. Moreover, three new classes of SSB(N) submarines were produced—the SSB(N)608, 616 and 640. During that time, there was great pressure to meet delivery dates for the SSB(N) submarines. Although there was considerable emphasis on noise reduction for these ships, this work was done within the framework of the established schedules. In addition to a time restraint, only a limited number of noise-reduction changes were permitted because of pressure to keep the cost of the ships reasonable.

[redacted]

NAVY 3.3(b)(1)(4)

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

APPENDIX B

[redacted]

NAVY 3.3(b)(1)(4)

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

The figure on this page is [redacted]

[redacted]