SYSTEM PLANNING CORPORATION

AN ASSESSMENT OF SMALL SUBMARINES AND ENCAPSULATION OF BALLISTIC MISSILES — PHASE II SURVEY

[redacted] FINAL REPORT
SPC 648

November 1980

System Planning Corporation (SPC)
Naval Sea Systems Command (SEA-92)
Lockheed Missiles & Space Company (LMSC)

Prepared for
Chief of Naval Operations (OP-963)
Department of the Navy
Washington, D.C. 20350

Draft Final Report

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Submitted under
N00014-79-C-0304

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RE: Classified References, Distribution Unlimited
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CONTENTS

AN ASSESSMENT OF SMALL SUBMARINES
AND ENCAPSULATION OF BALLISTIC MISSILES--PHASE II SURVEY

A. BACKGROUND

At the meeting of the Advisory Committee for the Assessment of Options for Construction of Strategic Submarines and Retirement of POSEIDON SSBNs on 18 October 1978, the Deputy Assistant Secretary of Defense (PA&E) (Strategic Programs) urged the Navy to undertake a more comprehensive review of missile encapsulation than had ever been done. In March 1979, an evaluation of SSBNs and small submarines with external encapsulated ballistic missiles was initiated [Ref. 1]. The evaluation was divided into two phases. Phase I of this evaluation assessed the technical feasibility of building and deploying small submarines with external encapsulated MX missiles as an alternative basing mode for the MX ICBM. The results of the Phase I assessment were promulgated by Reference 2.

The original purpose of Phase II of this evaluation was to assess the feasibility of building and deploying SSBNs with external encapsulated ballistic missiles and to compare them to TRIDENT class SSBNs. The specific objectives of Phase II as detailed in Reference 1 relative to SSBNs with encapsulated missiles are:

- Assess feasibility of building and deploying
- Assess targeting effectiveness
- Assess survivability relative to TRIDENT survivability
- Provide estimates of costs, schedules, and risks.

B. PURPOSE

At the meeting of the Advisory Committee on 21 February 1980, it was recommended that a survey of previous studies on missile encapsulation be conducted prior to the initiation of a Phase II study. The objectives of the survey were as follows:

- Determine findings and underlying assumptions of previous studies
- Identify new technologies that might change or alter previous findings
- Identify areas in which previous studies were deficient and required updating or additional study.

The purpose of this report is to discuss the findings of the survey that was conducted and to recommend, based on the survey and associated analyses, a course of action concerning the Phase II study effort.

C. FINDINGS OF THE SURVEY

The studies reviewed in the survey were performed from the mid-1960s through the mid-1970s. The most important of the studies were the Undersea Long-Range Missile System (ULMS) studies performed in 1969. The results of the ULMS studies strongly favored the bare missile concept because it permitted ship configurations no less attractive than the encapsulated missile launch mode and contained less development risk. Advancements which have occurred since these studies were completed would not alter their findings; missile technology advancements would apply to either a TRIDENT-type system or an encapsulated missile system.

Based upon the review of the ULMS and other studies, it is concluded that a Phase II study effort as originally specified in the study directive is not warranted. The following findings elaborate upon and form the basis for this conclusion:

- The "capsule" concepts are technically feasible.
- Many system trades and engineering problems remain for resolution in an engineering development sense, and no new science or advanced technological breakthroughs was found necessary.
- Credible current system costs do not exist, but there is no reason to expect that one could, in a study, confidently demonstrate a cost advantage with respect to TRIDENT-type systems.
- There is no significant decoupling of missile system-to-ship interfaces for encapsulated systems; however, "new" interface types are added (e.g., capsule-to-ship attachment).
- Certain major concerns would remain unresolved unless a properly funded and detailed concept definition phase was initiated (Phase II is envisioned as a study only); examples of these concerns are:

-- Complexity of logistics/maintenance methods

-- "Best" system solution to resolve post-launch capsule-ship clearance

-- Uncertainty with respect to the system's tolerance to shock

-- Uncertainty relative to performance, cost, and schedule confidence.

D. ADVANTAGES/DISADVANTAGES OF ENCAPSULATION

Concurrent with the review of previous studies, an assessment was conducted to identify possible advantages and disadvantages of SSBNs with external encapsulated ballistic missiles. Table 1 lists the areas that were examined and indicates those areas in which there might be possible advantages. These include improved flexible response capability, reduced manpower requirements, reduced submarine acquisition costs, and increased survivability during and after launch.

If there is a requirement for a split-launch flexible response capability on SSBNs, then either internal or external encapsulated ballistic missiles would permit the submarines to clear datum prior to missile launch. To accomplish this, the capsule would require a dwell capability or a capability to "swim" away from the SSBN before booster ignition. In either case, an enemy would be deprived of precise targeting information for a counterforce strike on the remaining missiles.

Since external encapsulated missiles would be inaccessible for servicing at sea, the missile technicians who normally perform this service on SSBNs would not be required. Although this would reduce the submarine crew size, additional shore support personnel would be required to service the missiles that failed at sea. The total personnel requirements would probably be smaller, however, than for the conventional SSBN.

Since the external carriage of missiles would result in a smaller submarine pressure hull, reduced submarine investment costs would probably result; however, the costs of complex capsules will tend to offset the reduced investment costs of the submarine. It would be necessary to determine total system costs (including RDT&E, investment, and O&S) to assess if there would be any overall system cost saving.

TABLE 1

RANGE OF POSSIBLE BENEFITS OF ENCAPSULATED BALLISTIC MISSILES

Mission	Yes	Possibly	Same	Unlikely	No
Improved massive-attack capability?			////		
Improved flexible response capability?		////			
Operations					
Improved covertness?			////	////	////
Reduced in-port time?			////	////	////
Reduced manpower requirements?	////	////			
Improved speed capability?					////
Improved missile accuracy?			////	////	////
Improved arming/safing procedures?				////	////
Improved missile availability?					////
Cost					
Reduced submarine acquisition costs?	////	////			
Reduced launcher/capsule acquisition costs?					////
Reduced systems costs?		////	////	////	
Survivability					
Increased survivability against active and passive sonar threats?			////	////	////
Increased survivability during and after launch?	////	////	////		

Increased submarine survivability is expected to result during and after launch because the submarine's offset launch capability would deny alertment of tactical or strategic surveillance until after the entire missile load (or partial load) is deployed.

Possible disadvantages of SSBNs carrying external encapsulated ballistic missiles are:

- Less covertness due to the possibility of greater hydrodynamic flow noise and larger target strengths
- Longer in-port time
- Reduced speed capability for the same size power plant due to less streamlined hydrodynamic shape
- More complex arming/safing procedures
- Reduced missile availability unless a very long mean time between failure (MTBF) for the missiles can be achieved.

E. PHASE II RECOMMENDATIONS

Based upon the review of ULMS and other studies, it is concluded that a Phase II study effort as originally specified in the study directive is not warranted. Major concerns and areas of uncertainty associated with encapsulated missile systems have been identified and it is unlikely that further studies alone would identify or be able to resolve any additional significant concerns. No Phase II study as originally specified is recommended at this time.

F. POSSIBLE ISSUES FOR FUTURE ANALYSIS

Since there are many disadvantages associated with external encapsulated ballistic missiles, as cited in Section D, further analyses might profitably be initiated to identify the situations in which their use may result in significant advantages. A requirements analysis could be undertaken to examine the following areas:

- Present or projected requirements for a split-launch capability on SSBNs
- Present and potential threats to SSBNs involved in split-launch or extended time period launch and the seriousness of such threats
- Counters to potential threats.

Other issues that could be usefully addressed would be (1) a comparison of special-purpose SSBNs fitted with external encapsulated missiles, and (2) questions dealing with optical path alignment of missiles and offset launch system accuracy. Estimated cost of the requirements analysis would be several hundred thousand dollars and would require about 6 to 9 months of effort.

If it is decided, based upon the requirements analysis, that there is a need for encapsulated ballistic missiles, then a concept definition study would be in order. Such a study would develop a complete specification of the proposed system based on engineering efforts. Its primary purpose would be to permit development of realistic estimates of program costs, schedule, and risk. The concept definition study would:

- Establish mission criteria and weapon system performance goals
- Establish force size and operational doctrines necessary to determine system effectiveness, basing, maintenance, and logistics requirements
- Perform detailed systems engineering and design trade-off studies to establish acceptable systems solutions relative to the technical areas of uncertainty
- Perform breadboard and prototype designs and tests (if required) in risk areas.

The estimated cost of this effort would be tens of millions of dollars and the effort would require in excess of a year.

Unless a concept definition study is performed, then confident statements on submarine costs cannot be made. To obtain credible submarine costs for a type of submarine that has never been built, a preliminary submarine design would be required. Estimated cost of this would be $5 to $6 million and would require in excess of 6 months of effort.

REFERENCES

1. Chief of Naval Operations, Ltr Ser 96/C192428, Study Directive for "An Assessment of Small Submarine and Encapsulation of Ballistic Missiles (U)," 6 March 1979, CONFIDENTIAL.

2. An Assessment of Small Submarines and Encapsulation of Ballistic Missiles-Phase I (U), Volumes 1, 2, and 3, System Planning Corporation Report 554, May 1980, SECRET/NO FOREIGN DISSEM/FORMERLY RESTRICTED DATA.

Appendix

STUDIES SURVEYED

CONTENTS

Strategic Systems Study II (U), NSWC/WOLX-152, Naval Surface Weapons Center, White Oak Laboratory, Silver Spring, Md., 30 September 1975

Volume 1: Executive Summary (not reviewed)
Volume 2: Further Requirements and Perceptions
Volume 3: Systems Concepts
Volume 4: Cruise Missile Technology
Volume 5: Missile Encapsulation Technology
Volume 6: Accuracy Technology
Volume 7: Submarine Platform Technology A

The present study is a follow-on to a previous study (see Strategic Systems Study, 31 May 1974) dealing with strategic systems. The initial study was conducted in FY 74 by a joint Navy/industry project team of experts who considered several scenarios reflecting changes in the U.S. technological, political, social, and economic positions as of the mid-1980s leading to the specification of systems attributes for both major and limited strategic missions appropriate to the post-TRIDENT time frame. Positive recommendations for potential future systems, principally for major missions, were made. The present follow-on study used the attributes previously developed to further explore strategic systems concepts, with emphasis on limited missions. Trade-off studies were performed; acquisition and 10-year O&M costs were estimated, and parameters such as feasibility, vulnerability, controllability, and overall military utility were considered. Six preferred systems involving surface platforms, submarines, cruise missiles, and ballistic missiles were identified. In addition, a major portion of the effort was devoted to the definition of R&D programs in critical technology areas necessary for making the future strategic system concepts identified in both studies a reality. Current state of the art, required R&D, funding, and time schedules were described for submarines, cruise missiles, encapsulation, and missile accuracy.

Volume 1: Executive Summary (not available at LMSC for review)

Volume 2: Further Requirements and Perceptions

It is the purpose of this volume to report on the further review (post Strategic System Study Group I (SSSG I)) of evolving strategic policy, noting any implications for strategic missions, new system concepts, or system attributes. Further, a brief chapter is included on perceptions of some aspects of U.S. strategic policy.

This report substantiates the work of the SSSG I in identifying trends in evolving policy and in defining strategic missions and system attributes. It appears that there are no changes contemplated that would require revisions to work of the SSSG I. Even the successful negotiation of a treaty on strategic offensive armaments along the lines of the Vladivostok understanding would not change this conclusion.

Volume 4: Cruise Missile Technology

This report describes the air vehicle technology required to develop an advanced Sea Launched Cruise Missile (SLCM) for operational use in the 1990's. Preliminary design concepts and technology assessments were developed for missiles unconstrained in envelope but sized to achieve 3,000-nautical mile and 5,500 nautical mile ranges. This report: (1) defines 1990 cruise missile capabilities; (2) identifies the critical cruise missile technologies and projects their state of the art to the 1990 time period; and (3) recommends research programs to assure the projected capabilities.

Volume 5: Missile Technology

The objective of this report is to identify critical technology areas requiring further effort, particularly in experimental investigations, so that confidence can be developed in the use of encapsulated Navy missiles in the ICBM range category.

The technology areas identified for further investigation in this report which are mainly capsule related are: (1) internal stowage on submarine; (3) hovering capsule control; (4) self-propelled capsule propulsion and noise control; (5) self-propelled capsule control; (6) missile launch from hovering and self-propelled capsules; (7) capsule pressure hull structures; encapsulated missile shock isolation, and (8) capsule power supply.

Volume 6: Accuracy Technology

The Accuracy Technology Committee of Strategic Systems Study Group II (SSSG II) was formed to study and recommend areas of technology which should be supported today in anticipation of the accuracy requirements of future sea-based strategic systems established by the study of SSSG I and updated by the Systems Concepts Committee of SSSG II. This report is organized into four parts. The objectives of study, the justification for improving weapon system accuracy, and the results of the study are explained. The principal factors which affect weapon system accuracy, describing today's capabilities and presenting concepts which can lead to significant improvements in performance, are addressed. The status of specific technologies, describing past achievements, current activities, and feasibility of future advances in technology are examined. The recommendations for support of accuracy technology are summarized.

Volume 7: Submarine Platform Technology, A

This volume explores technology alternatives which have considerable influence on the utility of strategic submarines in the post 1985 time frame. Although the focus of the overall study has been directed toward new strategic options, the submarine technologies considered herein have been addressed from a much broader viewpoint. Therefore, the alternatives are considered applicable to undersea strategic platforms in general and may influence future development of attack submarines and other naval vessels.

Volume 8: Submarine Technology, B

This report was prepared to identify critical advanced technology areas as a result of examining unusual SSBN concepts. Recommendations are also provided for investigation in these technology areas so that confidence can be developed in potentially high payoff configurations. The study approach involved the development of preliminary advanced SSBN concepts with the potential advantages of: (1) economic proliferation/replacement of substantial missile throw-weight; (2) high survivability from missile backtrack threats; and (3) missile size flexibility.

Strategic Systems Study (U), NDLX-85, Naval Ordnance Laboratory, White Oak, Silver Spring, Md. 31 May 1974, SECRET RESTRICTED DATA.

Volume I:	Executive Summary (not reviewed)
Volume II:	Systems Requirements
Volume III:	Technology (and Volume III Annex)
Volume IV:	Systems Concepts
Volume V:	Selected presentations to SSSG (Parts A&B)

The Strategic Systems Study had as its objective the formulation of advanced strategic systems concepts for sea-based deterrence for the mid-1980s to 1990 time frame. The participants comprised a joint Navy/industry team of experts representing several Navy laboratories and defense-oriented companies under the direction of the Naval Ordnance Laboratory. The study initially considered changes in the U.S. technological, political, social and economic positions of the mid-1980s and also responded to the President's request for a "flexible range of strategic options" by defining six distinct types of missions. Requirements and system attributes were specified for each mission. The present and future technologies of platforms, missiles, reentry bodies, warhead, guidance and control, C^3, and logistics were examined and formed the bases from which several advanced strategic systems were synthesized. Two approaches were used in developing systems concepts: (1) evolution from existing and currently approved systems, such as TRIDENT, to the new options requested by the President; and (2) newly conceived systems expressly tailored to the new options. A typical example of nonevolutionary approach is a small, slow, bottom-sitting submersible carrying encapsulated externally stowed missiles. General areas for future R&D necessary for the implementation of advanced strategic systems and subsystems are identified in the study. More precise specifications of a strategic R&D program will be addressed in follow-on studies.

Volume I: Executive Summary (not available [at LMSC] for review)

Volume II: Systems Requirements

Various new requirements driven by changing international politics, economics, technology, and new arms control treaties could have a large impact on future sea-based systems. It is the intent of this study to analyze these new requirements (beyond TRIDENT) and to propose system concepts which will ensure the preservation of our most effective strategic capability.

The existing U.S. Navy strategic systems and trends in U.S./U.S.S.R. technology are presented. The trend data included submarine displacement, length, speed, shaft horsepower, and radiated noise and missile weight, range, payload, yield, CEP, and patrol area.

Existing treaties are summarized, future treaties are discussed, the emerging strategic policy is presented, and various scenarios are developed. Based on the evolving strategic policy and the various scenarios, seven missions were selected as best representing the projected policy in the post-TRIDENT time frame. Based on these missions, the strategic system attributes (overall system, C^3, platform, missile, and reentry body) are defined.

Volume III: Technology

This report sets forth the elements of technology, current and future, which form the basis for the selection of the weapon system options of Volume IV to meet U.S. future strategic requirements as elaborated in Volume II. This volume consists of principal sections on system accuracy, missiles, platform design, and C^3. The section on missile technology includes warheads, reentry systems, missile configuration, and the important area of encapsulation. The platform section contains information on design options and a synopsis of the most likely antisubmarine threats. This volume is not meant to be an exhaustive treatment of all strategic weapon system technology, but simply a resume of those factors important to the generation of the system concepts described in Volume IV.

This report presents many design alternatives and describes the present and future state of the art.

Volume IV: Systems Concepts

Previous phases of the Strategic System Study addressed possible future missions for U.S. strategic forces in response to the President's request for a "flexible range of strategic options" and specified attributes for six distinct missions, the principal new system features being effectiveness against hard targets, low collateral damage, and enduring survivability of a Strategic Reserve Force. Furthermore, the technology of components and subsystems that could comprise strategic systems was examined extensively. The systems concept task required satisfying all missions and their attributes using the current and projected technology examined during the study.

The report discusses an evolutionary approach to systems [illegible] to accomplish the six missions defined in Volume II. Thi[illegible] lutionary approach uses those Navy FBM strategic systems now in the field or under development as a base point and builds additional capability into the system through design changes and improvements in platform, booster, guidance, and RB subsystems. Most of the proposed evolutionary systems use existing platforms including TRIDENT. However, the most advanced system addressed requires a completely new platform and launching procedure.

The advanced systems are essentially variations of the same generic concept, i.e., employing small submersibles with external encapsulated missiles. Two variations are: operational areas (CONUS and broad ocean), and ship propulsion (nuclear and non-nuclear). The intent of these systems is to derive an economical system.

Underwater Launched Missile System Canister Design, D2-126242-I, The Boeing Company, 15 December 1969, UNCLASSIFIED

This document expands on the canister requirements for an underwater Launched Missile System (ULMS), as proposed in Volume 6 of the 1st STRAT-X Committee Report. Functional flow, environmental requirements, and interfaces are identified. Preliminary design sketches, graphs, and calculations for the primary structure and missile suspension system are summarized. Subsystems are identified and discussed. The feasibility of design and construction of horizontally stowed missile canisters for missiles up to 225,000 pounds is verified. The procedures used are considered applicable to the definition and design of other submarine canister systems.

A canister exceeding the performance requirements of the Underwater Missile System (ULMS) as proposed by the STRAT-X committee report, Volume 6, can be designed and constructed. Requirements for a canister to contain a 225,000 pound missile 90 inches in diameter and 84.3 feet long to be launched at speeds and depths in excess of present-day (1969) Polaris submarine system capabilities have been proposed. A submarine-canisterized system configuration has been conceived and described in Boeing document B2-125961-2, Preliminary ULMS Submarine Configuration for Horizontal Missile Stowage.

Supplemental preliminary design has been accomplished herein to verify the feasibility of the canister.

The canister design proposed is an internally ring-stiffened structural shell with dogged lids that open for missile launch at the sea-air interfaces. The canister is approximately 9.1 feet outside diameter by 92.5 feet long and weighs approximately 130,000 pounds alone and 355,000 pounds with the missile. The canister is carried horizontally on the submarine supported by a trunnion and latch 3 point suspension system. The missile is supported laterally inside the canister by air bags and restrained longitudinally by a belleville spring system. Integrated electrical, hydraulic, pneumatic, ballast and environmental control systems supplement the structural-mechanical and missile support systems to provide a canister which provides the ULMS performance requirements.

Canister release is initiated hydraulically from the submarine and completed by buoyancy and dynamic pressure forces. Position buoyancy carried the canister to the surface where sensors initiate canister opening and missile launch.

Cost Effectiveness Model for Strategic Missile Submarines (U), Volumes I and II Lockheed Missiles and Space Company/MSD, July 1968, Revised October 1969.

A computer-programmed methodology for evaluating possible future SSBN deterrent systems from a cost-effectiveness viewpoint is described. Although intended primarily to optimize ship characteristics and operational procedures for the LRC-3 Weapon System, other types of missiles or their parametric variations can be accommodated. The expected number of missiles on station, secure from enemy detection, was selected as the measure of effectiveness and total system life-cycle costs (considering support system inventory as well as deployable elements) are considered in the optimization process.

With the exception of some built-in simulation routines used within the operational effectiveness model, the programs are written in Fortran IV. A Univac 1107 computer can accommodate the entire program, including simulation.

Detectability of FBM Submarines, General Dynamics/Electric Boat Division, 23 May 1969.

This report compiles the results of studies which made a comparison of the detectability of three basic missile submarine hull configurations, i.e., single hull, double hull (bare missile) and encapsulated missile.

The advantages and disadvantages from a self noise standpoint from the following seven noise sources are discussed: (1) flow induced noise-plating; (2) flow induced noise--roughness, fairness, dome and sail; (3) flow induced noise--free flood holes, "rattles and tones" etc.; (4) propeller; (5) machinery; (6) steam and; (7) crew. A tabular comparison of the hull configurations is presented.

Submarine-Related Information Launching Mode Selection: Undersea Long-Range Missile System, General Dynamics/Electric Boat Division Report to NAVSEC 6110, 1 February 1969.

This report compares the bare missile launching mode with the encapsulated launching mode. This analysis is based principally on a family of nine ship configurations, five bare mode and four encapsulated. The missiles and capsules were selected from a family of missile designs, all potential candidates for the ULM System. For the vertical stowage schemes, the shortest missile/capsule is preferred because overall length strongly influences hull depth. For the horizontally stowed encapsulated missiles, the largest candidate was specified.

The design starting conditions are enumerated and the submarine point design characteristics are listed. A matrix summary of configuration characteristics is included. Launching features, such as depth, control, launch rate and sequence are compared together with submarine hydrodynamics, missile environmental control and missile load-off load capabilities. Survivability features are compared such as concealment and defensive capability. The report concludes that the preferred launching mode is bare.

Missile Stowage/Launch Mode Comparison (Ship Related): Undersea Long Range Missile System (ULMS), General Dynamics/Electric Boat Division Report 14 January 1969.

General Dynamics/Electric Boat Division analyzed whether the bare missile or encapsulated missile concept of stowage and launch is more feasible or desirable than the other. Ship configuration and other technological studies have been completed to the point where an evaluation can be made and conclusions reached.

The objective of this report is to compare and evaluate those ship related parameters of the bare and encapsulated missile stowage/launch concepts to contribute to a basis for a decision by the Strategic Systems Project Office as to which concept to select.

In the course of study, certain parameters of the ship configuration and its performance capability have been found to be sensitive to the two basic missile stowage/launch concepts under consideration. This report concentrates on these areas. Electric Boat Division has evaluated these parameters and reached conclusions.

Results of studies strongly favor the bare missile concept. This concept permits ship configurations no less attractive than the encapsulated missile stowage/launch mode, provides greater weapon system capabilities, and contains less development risk.

LRC3 Preliminary Site Safety Study (U), Lockheed Missiles and Space Company/MSD 27 November, 1968.

This study evaluates the Refit Facilities impact of several encapsulated missile submarine configurations and a baseline bare missile submarine configuration.

Hydrodynamics Contribution to the Horizontally Launched, Aft Constrained, Capsule Trunnion Study (U), Lockheed Missiles and Space Company, 6 September, 1968.

The trunnion force and moments in the pitch and yaw planes and also the force in the axial direction were computed for five missile/capsule configurations in which an aft launch trunnion is employed to support the capsule during erection to release.

Long-Range C3, FY 1968 Final Report (U), Lockheed Missiles and Space Company, 2 August 1968, Secret.

Appendix A: Missile System
Appendix B: Guidance
Appendix C: Fire Control
Appendix D: Navigation
Appendix E: Launching and Handling
Appendix F: Capsule
Appendix G: Operations Support and Logistics

This document is a report on work accomplished during fiscal year 1968. The main body of the report is a summary of the various studies and investigations conducted. Detailed information and data are included in Appendices A through G.

The principal effort was directed toward investigation of the feasibility of adapting major elements of the POSEIDON FBM to an advanced, Undersea Long-Range Missile (ULM) type weapon system. In this investigation, the minimum change missile is named the Long Range C3 (LRC3).

The work reported on herein is the result of the cooperative efforts of: General Electric Company, Ordnance Department (Fire Control); Massachusetts Institute of Technology, Instrumentation Laboratory (Missile Guidance System); Lockheed Missiles and Space Company (Missile, Capsule Weapon System, System Analysis, and Operations Support and Logistics); Sperry Rand Corporation, Systems Management Division (Navigation System); and Westinghouse Electric Company, Missile Launching and Handling Department.

Preliminary conclusions are enumerated in many of the individual studies and investigations described in this report. Collectively, they support the feasibility of developing a long range minimum change C3. The work further indicates endorsement for the missile in either the bare internal or encapsulated external stowage configuration. With the exception of isolated items within some of the studies, no analysis was made concerning the feasibility of weapon system integration with a submarine. Future plans, to IOC, are presented for each subsystem.

Missile System

Preliminary conceptual design studies of various missile configurations have revealed feasible and attractive approaches to fulfill the potential needs of a new sea-based strategic weapon system. Missile concepts capable of substantial increases in performance when compared to the POSEIDON (C3) missile have been derived; sensitivities of missile performance to changing requirements developed; and some preliminary analyses of feasibility accomplished. In this formulation period these studies have provided the missile system basis for overall weapon system analyses and the continuing evolution of major subsystem requirements. Study details are provided in Appendix A.

Guidance System

Studies have been made to investigate which guidance system configuration will be most suitable for LRC3. Five different guidance configurations were chosen for study, each a greater departure from the POSEIDON MK4. Final selection awaits final groundrule definition and constraints. Study details are provided in Appendix B.

Control System

The major effort in the fire control area initially was to evaluate the new requirements of the LRC3 Weapon System and determine the resulting requirements for fire control equipment. As key problem areas developed, specific studies were initiated and overall effects were continuously evaluated. An objective of the study was the determination of the suitability of POSEIDON equipment for the LRC3 weapon system. Study details are provided in Appendix C.

Navigation System

The design and performance requirements for the LRC3 navigation subsystem cannot be rigorously defined at this stage of the LRC3 weapon system life cycle. Therefore, the obectives of the navigation study effort in FY 68 were to formulate the initial concepts for the LRC3 navigation subsystem and to contribute to the advancement of overall program plans for the LRC3 weapon system. Study details are provided in Appendix D.

Missile Launching and Handling

The handling, submarine stowage, and launching of large missiles for the encapsulated missile concept were studied. Missile/capsule separation and capsule producibility were also investigated. The capsule handling investigation evaluated a range of handling methods and the feasibility of the system selected was investigated to insure that there would be no major difficulties. In the missile/capsule separation study, the separation performance of various possible configurations were evaluated with respect to the missile and capsule dynamics during separation; particular emphasis was placed on the capsule plunge-back motions. The capsule producibility investigation was devoted to the examination of production processes and design features to minimize production costs. Study details are provided in Appendix E.

Capsule

The program of system studies, design investigation, and tests conducted during FY 68 concerning the capsule for the LRC3 weapon system is summarized in this section. Complete documentation of the capsule studies is presented in Appendix F. The subject studies were planned and executed so as to establish credibility of the capsule system and refine and/or further develop the analytical tools necessary for capsule system trade-off studies and performance evaluation. These objectives were achieved.

Operations Support and Logistics

Studies were selected to determine the impact of various concepts on existing FBM operational support systems capabilities and to provide a preliminary measure of feasibility of the proposed changes in operations and logistic support functions in terms of their relative cost, time and performance. Studies details are provided in Appendix G.

Appendix F: CAPSULE

The missile capsule system study objectives for FY68 were to establish credibility and to develop and refine the analytical tools necessary for capsule system trade-off studies. These objectives were achieved.

The feasibility of utilizing a capsule to protect a missile during its life cycle, from encapsulation to launch, was defined during a study of the Underwater Long-Range Missile System (ULM) for the STRAT-X committee in 1967. During FY 68 additional studies and tests on specific problem areas were conducted to increase the credibility of previous studies. A model test verified the capsule performance in both the release and ascent modes. Techniques required to separate the end closures were verified by test. Specific studies were conducted in FY 68 regarding shock mitigation system requirements, missile/capsule separation, missile environmental protection, capsule structural design, and materials.

Although a Preliminary Technical Development Plan (PTDP) was not required in FY 68, data for this document was developed to establish interfaces between subsystems, preliminary requirements and interface documents were generated for the missile capsule and stowage release system. Alternate concepts were generated by both the missile capsule and release systems covering a range of missile sizes.

The program for simulation of underwater trajectories was improved by expanding it to include the missile capsule separation event and the plunge-back trajectory of an unopened capsule. A new program was created to analyze the gas dynamic characteristics related to missile/capsule separation. Effects of underwater explosions on sizing of the shock mitigation system were investigated. Buoyancy of the capsule and the stiffness of the release system were found to have a major impact on the shock mitigation thickness requirement.

ASP/AUWS Capsule Hydrodynamics Based on Davidson Laboratory Tests (U), LMSC-D020402, Lockheed Missiles and Space Company, Inc., Sunnyvale, CA, June 1968.

Submerged scale model tests were conducted at the Davidson Laboratories, Stevens Institute of Technology, to determine the hydrodynamic characteristics of various STRAT-X capsule configurations. These tests were conducted to determine the force and moments acting on the capsule in both the free flight and capsule/submarine interaction modes.

Proposed Conversion of SSBN 598/608 to Long-Range POSEIDON Missile, General Dynamics/Electric Boat Division, January 1968

This study examined the conversion of 10 submarines of the SSBN-598 and 608 Class to a new force of missile carriers for the Long Range C3 (LRC3) missile. The study adopted one baseline scheme for horizontally stowed encapsulated missiles. Alternate concepts are briefly discussed.

These ship design concepts were developed only in sufficient detail to prove Engineering/Design feasibility and the results are presented in such a manner that the information could be used as design criteria and guidelines by the ship designer during Contract Definition and Preliminary Design.

Missile Sizing and Weapon System Interfaces, Final report (U), LMSC-B182778, Lockheed Missiles and Space Company, 15 June 1967.

Appendix A: Missile Design and Performance
Appendix B: Capsule Design and Performance
Appendix C: Missile/Capsule Costs
Appendix D: Weapon System Interface
Appendix E: Operational Readiness and Reliability
Appendix F: SSBN-E System

This report (including appendices) presents the results of Missile Sizing and Weapon System Interface studies performed in support of the STRAT-X study on the Undersea Long-Range Missile (ULM) system.

The ULM system is a self-contained weapon system with a force of specially configured submarines armed with SLBM missiles and operating from U.S. ports.

The missile selected for the ULM system is a long-range, conventionally configured, two-stage, solid propellant, 4,000-lb throw-weight ballistic missile based on 1967 technology, postulated missions, operational criteria, and STRAT-X ground rules. The missile is stowed horizontally in a capsule external to the submarine pressure hull.

The "Missile Sizing" section and Appendix A of this report dealt with the determination of preliminary design, performance data and ROM costs for a matrix of missiles specified by STRAT-X. In addition, a system optimization study was conducted to establish the missile configuration and performance for the Undersea Long-Range Missile System missile. This optimization considered the establishment of: missile range, throw-weight per missile, number of stages, missile dimensions, number of missiles per ship, and accuracy requirements.

The "Weapon System Interfaces" section and Appendixes B, D, and E of this report was a three-part study: (a) examination of POLARIS patrol history to determine missile operational readiness reliability; (b) consideration of effects of stellar inertial guidance on ULM accuracy; and (c) determination of capsule launch criteria. In each part of this task, interface requirements were established and coordinated between the tactical systems. The missile capsule task determines missile capsule launch criteria and provides conceptual design for missile protection from assembly facility to first stage ignition. It shows compatibility with submarine design and operational modes. It also defines related submarine requirements, problem areas, shows solutions, and defines risks and related development and costs.

Appendix A: Missile Design and Performance (not summarized)

Appendix B: Capsule Design and Performance

Appendix B studies show that the design and construction of the capsule and its components do not require technological breakthroughs. All required techniques and hardware are within current state-of-the-art technology and in many cases are readily available or adaptable from existing weapon systems.

In the area of hydrodynamic performance, underwater trajectories of similar capsules have been under study for some time, and accurate predictions are possible for the ULM system, as confirmed by analytical methods developed and corroborative small scale-model tests.

Two performance areas remain where development work is necessary to confirm the system design. The first concerns capsule behavior during exit from the submarine. The hydrodynamic interaction between the capsule and submarine and between the capsule and parts of the submarine stowage doors released during ejection is complex. Additional analysis and scale-model studies will confirm the prediction of clean separation under all operating conditions. The other area needing study involves capsule behavior at missile exit. Here, again, definition of the interaction between the two, and of the behavior of the spent capsule, will benefit from further analysis augmented by tests.

Appendix C: Missile/Capsule Costs

This appendix compiles the costs associated with the RDT&E, investment, and operating phases of the baseline ULM missile system and missile capsule. The total 10-year cost (1967) for the missile system is $8,237,000,000 and for missile capsule $292,000,000. Costs data is presented only for the baseline ULM configuration at three force sizes.

Appendix D: Weapon System Interfaces (not summarized)

Appendix E: Operational Readiness Reliability (not summarized)

Appendix F: SSBN-E Systems

The submersible ship, ballistic missile, nuclear powered-external (SSBN-E) system combines a modified existing sea-based system (POSEIDON C-3) with a new undersea long-range missile (ULM).

This system offers the advantages of being relatively inexpensive because of the existing operational basing, ships, and facilities, effective because of the combined POSEIDON and ULM payloads, and survivable because of the greatly expanded operating area.

The SSBN-E system concept exists in parametric form only. Further design studies will define the system as it would ultimately be produced. A hypothetical baseline system is herein described for purposes of depicting the operational concepts and the effects of such a system.

Phase-3-(Final) STRAT X Report to NAVSEC 6110, General Dynamics/Electric Boat Division, 10 June 1967.

Appendix E: Ship Design
Appendix E-1: Ship Design
Appendix E-2: System Descriptions
Addendum to Appendix E-2 System Descriptions

This four-volume report was the final Electric Boat Division input to the STRAT-X Study under NAVSEC direction.

Appendix E covers the baseline submarine description and the following on the missile/capsule systems: comparison of stowage schemes; horizontal stowage and launching scheme; missile capsule compensation; missile capsule cooling system; missile capsule handling gantry; missile capsule transfer time study; and missile capsule unloading time study.

Other ship elements discussed are: ULM submarine modular design; ship construction concept; sonar detectability; and corrosion protection.

Appendix E-1 covers additional studies in support of the basic ship concept: ULM submarine hardening; miscellaneous studies of electronic aids to bottom sitting, feasibility of using power plant waste heat for missile capsule heating, ULM Diesel-Generator-Battery study and hull access patches; ULM Diesel Electric Submarine Study; initial submarine construction costs; and ULM Submarine Schedule "A".

Appendix E-2 covers the ULM Submarine Ship Systems, including the added systems, retained systems, modified systems, and deleted systems.

The Addendum to Appendix E-2 covers the system descriptions for the propulsion system, external communications, and ECM.

Undersea Long-Range Missile (ULM) System, Final Draft, LMSC-B135994, Lockheed Missiles and Space Company, 30 May 1967.

Appendix A: System Cost
Appendix B: System Effectiveness
Appendix C: Shock Hardness
Appendix D: Communications
Appendix E: Ship Design
Appendix F: Ship Propulsion
Appendix G: Navigation
Appendix H: Fire Control
Appendix I & J: Missile Design
Appendix K: Logistics Plan (AKA LMSC-B135991)

The Secretary of Defense on 1 November 1966 initiated a comprehensive study, termed STRAT-X, to examine "future ballistic missile basing concepts and missile performance characteristics required to counter potential Soviet strategic offensive forces and ABM proliferation." To establish a frame of reference for study purposes, the primary function of all candidate systems was taken to be: provision of economic surviving payload for targeting against the Soviet U/I base, with flexibility to do the counterforce and controlled response missions as desirable secondary objectives.

The Undersea Long-Range Missile (ULM) System description contained in this report is the result of work accomplished by a Navy and industry team organized to support the STRAT-X Panel considering the submarine basing concept.

To enable comparative evaluation of candidate systems with respect to specific criteria, the STRAT-X Group established standards applicable to all systems that necessarily imposed constraints on system formulation and design. As the study progressed, ground rules were defined within each system to resolve disagreement between the team providing the military service input and the STRAT-X Group, or to settle on a specific approach where imperfectly known parameters precluded a definite tradeoff analysis.

The ULM weapon system is a force of specially configured submarines armed with encapsulated SLBMs and operating from U.S. East and West Coast ports. The ULM system is based on an integrated systems approach derived from the POLARIS/POSEIDON FBM weapon system background, demonstrated and conservative technologies, and the inherent advantages of mobility and survivability offered by broad ocean deployment.

The selected system configuration is composed of the following five subsystems and base suppport.

Submarine. The ULM-class submarine is able to carry, sustain for long patrol periods, and deploy 24 encapsulated long-range missiles. It can operate freely and quietly in large ocean areas, provide the power for maneuvering, for crew life support and for all weapon subsystems.

Navigation system. This system combines the routine ship's navigation capabilities with the generation of data on position, heading and velocity to the accuracy needed for fire control computations.

Integrated fire control system. This system receives navigation data, targeting-fuzing inputs, and missile guidance generated data. It computes missile guidance presettings and fuzing data and generates guidance platform orientation and fuze set signals for all missiles. It also performs limited missile monitoring and pre-flight checkout functions.

Missile system. This system consists of a two-stage solid propellant booster and a post-boost vehicle with reentry system, propulsion, and control. The system also includes the missile capsule utilized for stowage and for launch.

Non-tactical test instrumentation. This system is located in the submarine for use in acquiring, processing, and recording weapon system performance data and for checking out missile equipment during installation and performance tests of the ULM weapon systems. It is capable of integrated operations with National Test Ranges, test facilities, and instrumentation support ships.

This volume summarizes the material presented in detail in its accompanying eleven appendices.

Appendix A: System Cost

This cost appendix was prepared to provide the STRAT-X study with the rationale and sources used in determining those cost estimates presented in the Final Draft of the Undersea Long-Range Missile System Report. The costs indicated in the breakdown are in millions of 1967 dollars and are grouped under RDT&E, Investment, and 10-year Operating Cost categories. Certain costs were fixed for all systems by STRAT-X guidelines. Remaining costs were provided by various naval and civilian industrial organizations with extensive experience in submarine missile system design, construction, and operation. Cost lists are consistent both with baseline force levels and applicable STRAT-X guidelines.

Appendices B, C, D (not reviewed or summarized)

Appendix E: Ship Design (General Dynamics, Electric Boat Division, 10 June 1967)

The ship design studies reported within this volume were conducted for the Naval Ship Systems Command by the Electric Boat division of General Dynamics.

In developing the ship concept, many design alternatives and ship configurations were investigated; time and resource constraints made it impossible to investigate all combinations of ship characteristics and parameters. The final baseline ship was selected as a technically feasible concept, the result of preliminary tradeoff analyses. Because the threat analysis was being developed in parallel with the system, clean-cut tradeoffs based on the threat were difficult to define. System refinement must be made in all areas to ensure that the optimum cost-effective configuration is carried into development.

The baseline ship concept has the following physical characteristics based on the criteria selected for the baseline system during the Phase 3 ULM submarine parametric design studies. The ship has a cylindrical hull constructed of HY80 with encapsulated missile stowed horizontally, three deep, in four bays port and starboard, in the free flowing area.

The baseline ULM submarine configuration concept also included the study of missile capsule systems (horizontal stowage and launching scheme), design criteria for the ULM submarine modular design, construction concepts (i.e., analysis of construction elements, facility concepts and plans, production plans, and modular construction); sonar detectability (i.e., submarine noise and target strength); and corrosion protection.

Appendices F, G, H (not reviewed or summarized)

Appendix I: Missile Design

This is a one-page report referring to "Missile Sizing and Weapon Systems Interfaces, Appendix A, Missile Design and Performance (U)," LMSC-B182778.

Appendix J: Capsule Design

This is a one page report referring to "Missile Sizing and Weapon System Interfaces, Appendix B, Capsule Design and Performance (U)," LMSC-B182778.

Appendix K: Logistic Plan

This study established a conceptual definition of a ship refit and missile facilities logistic system to support the ULM system. The basic assumption for the conceptual definition was that once a submarine became an operational element of a ULM force, the patrol/in-port cycle would never be interrupted for extended submarine overhaul during the weapon system life cycle. The study was completed for the detail necessary to permit description of the overall maintenance concept, the facility requirements for submarine and missile acquisition and operational support, and to permit a preliminary assessment of more significant aspects of numbers of personnel, maintenance requirements, and costs.

The ULM weapon system force level included 323 submarines operating out of three bases, two on the East Coast and one on the West Coast. Various patrol/refit cycles were evaluated to establish length of patrol, optimum missile availability, minimum acceptable missile availability, etc. The basic cycle was an 83-day/21-day cycle, with the 21-day refit period spanning the time from actual entry into port until the submarine is ready to sortie.

The Submarine Refit Facility (SRF) will be a single-purpose facility designed for quick turn-around maintenance of the ULM class submarine. The SRF is the operations and maintenance base for the ULM submarine during its entire life cycle. The SRF arrangement and capability will be similar at each of the three bases.

Missile facilities are required to assemble the missiles to meet the submarine outload and to provide operational support for the missiles on the deployed submarines. The three facilities are different in arrangement and capability, one of the East Coast facilities provides for the assembly of missiles for both East Coast facilities. All three facilities provide operational support. Investment and annual operating costs are given for each of the three SRF and missile facilities.

Undersea Long-Range Missile System (U), Phase 2 Report, General Dynamics/ Electric Boat Division, 20 March 1967.

The Phase 2 ULM submarine baseline design is Configuration C from the Phase I interim STRAT-X Report dated 6 February 1967. This design was chosen as the best compromise for the ULM ship mission and mode of operation. The ship has a rather barge-like appearance because it is primarily designed as a reliable, cost competitive mobile missile platform. Speed and maneuverability were secondary considerations.

Missiles are encapsulated--stowed horizontally and parallel to the pressure hull to minimize the outer hull envelope and draft. Missile load varies from 12 to 16 and 32. Capsule launching is through the sides of the ship. This provides a surface launching capability, individual jettisoning in case of capsule flooding and ensures capsule launching well outboard of the fairwater and rudders.

Trade-off studies include both horizontal and vertical stowage of encapsulated missiles, speed vs. number of missiles, speed vs. shaft HP, alternate pressure hull materials, alternate outer hull materials, sound damping of outer hull, internally damped structures, and external acoustic treatments.
Propulsion plant variations include: pump jet propulsion, diesel and gas turbine propulsion in relation to vulnerability, and 15,000 and 7,500 SHP nuclear propulsion.

Stowage and Launch Mode Comparison Undersea Long-Range Missile System (U), Interim Report, General Dynamics/Electric Boat Division, 6 February 1967.

This was the first Electric Boat Division Progress Report submitted to NAVSEC for the STRAT-X Committee studies.
The report covers progress on the following NAVSEC Task assignment: Analyze and evaluate at least four basic ship concepts-single hull, tandem hull, egg crate and catamaran hull.
From each of these concepts, make parametric excursions to optimize the configuration in areas of propulsion, missile stowage, number of missiles, and type of missiles.

The NAVSEC task assigned a number of parameters to be considered in the studies including depth, defensive weapons, speed, combat ready time, missile range, accuracy, missile encapsulation, and navigation.

The report includes four point designs for encapsulated missile submarines with parametric variations and trade-offs.

Project TIDAL--Sea-Launching Encapsulated Missiles as Advanced Sea-Based Deterrent, Naval Missile Center, 18 November 1966.

The purpose of Project TIDAL was to demonstrate the feasibility of encapsulating POLARIS missiles as an advanced sea-based deterrent. A one-third scale POLARIS model was used to accomplish the following objectives of the program: (1) Provide a capsule that will protect the missile from pressures present at launch depth; (2) Provide a method of separating the encapsulated missile from its capsule; and (3) Provide a method of causing the encapsulated missile to dwell or hover at a predetermined depth for a predetermined time.

Static tests were conducted on land in a firing tank.

The method employed to encapsulate the missile is to house it in a tubular pressure hull which has removable end covers. The covers are ejected as the capsule is floating vertically at the water's surface. Diaphragms under each cover continue to keep the missile dry until the time of missile/capsule separation. The method used to separate the missile from its capsule is to launch it out of the capsule under its own thrust. The motor exhausts into the water rupturing the bottom diaphragm, and the top diaphragm is ruptured by the missile as it leaves the capsule. A pneumatic buoyancy control mechanism attached to the bottom cover is used as the method for causing the capsule to dwell about a predetermined depth prior to raising it to the surface for launch of the missile.

The conclusions were as follows: (1) Launching of a POLARIS A3 missile from a tubular capsule floating vertically in the water (with a diaphragm at the top and bottom ends) appears to be feasible; (2) Based on the design investigated, a dwell mechanism is a feasible method of causing the capsule to dwell about a predetermined depth; and (3) The base pressures expected at ignition are less than 160 psi, which is approximately the pressure the POLARIS A3 is designed to meet.

Theoretical Evaluation of Tubeless Simple Flotation Concepts for Advanced Sea-Based Deterrence, Naval Air Engineering Center, 16 June 1964

The conceptual designs and preliminary performance calculations are presented for launching ballistic missiles from ships at sea employing simple flotation principle.

The basic system includes the use of a high strength capsule to protect the missile at deep submergence. Upon release from the delivering vessel, the capsule assumes a vertical altitude and is accelerated toward the surface by the excess of buoyancy over weight. At or near the surface, the capsule is shed and the missile ignited. Velocities up to 100 feet per second can be achieved with reasonable capsule weights. Some variances of the system can be used on either submarines or surface vessels.

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: SPC-648
2. GOVT ACCESSION NO.: AD-A094 336
3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle): AN ASSESSMENT OF SMALL SUBMARINES AND ENCAPSULATION OF BALLISTIC MISSILES -- PHASE II SURVEY
5. TYPE OF REPORT & PERIOD COVERED: [redacted] Final Report
6. PERFORMING ORG. REPORT NUMBER: 80-4191
7. AUTHOR(s):
System Planning Corporation (SPC)
Naval Sea Systems Command (SEA-92)
Lockheed Missiles & Space Company (LMSC)
8. CONTRACT OR GRANT NUMBER(s): N00014-79-C-0304
9. PERFORMING ORGANIZATION NAME AND ADDRESS:
System Planning Corporation
1500 Wilson Boulevard
Arlington, Virginia 22209
10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS:
Studies Management Branch
Systems Analysis Division, Office of Chief of Naval Operations, Department of Navy, OP-966
Washington, D.C. 20350
12. REPORT DATE: November 1980
13. NUMBER OF PAGES: 29
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office):
Office of Naval Research
Department of the Navy
800 N. Quincy Street
Arlington, Virginia 22217
15. SECURITY CLASS. (of this report): UNCLASSIFIED
15a. DECLASSIFICATION DOWNGRADING SCHEDULE: N/A
16. DISTRIBUTION STATEMENT (of this Report)

DISTRIBUTION STATEMENT A
Approved for public release;
Distribution Unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)
18. SUPPLEMENTARY NOTES
19. KEY WORDS (Continue on reverse side if necessary and identify by block number)
Missile encapsulation, MX missiles, submarine ballistic missiles, Undersea Long-Range Missile System (ULMS)
20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A survey of previous studies on missile encapsulation was conducted. Based upon the results of this survey, it was concluded that a Phase II study effort as originally specified in the study directive is not warranted.