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AN ASSESSMENT OF SMALL SUBMARINES AND ENCAPSULATION OF BALLISTI--ETC(U)

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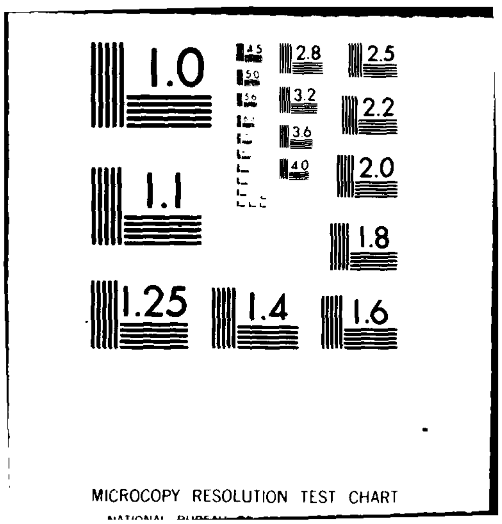
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SYSTEM PLANNING CORPORATION

AN ASSESSMENT OF SMALL SUBMARINES AND ENCAPSULATION OF BALLISTIC MISSILES — PHASE I

UNCLASSIFIED VERSION
EXECUTIVE SUMMARY

May 1980

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

Prepared for
Deputy Under Secretary of Defense
for Research and Engineering
(Strategic and Space Systems)
Washington, D.C. 20350

DEPARTMENT OF THE NAVY
OFFICE OF THE CHIEF OF NAVAL OPERATIONS
WASHINGTON, D.C. 20350

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1. This Summary is published at the request of DUSDR&E (SSS). This unclassified version presents only those findings of SPC Report No. 554 which can be discussed in an unclassified report.

2. Enclosure (1) is forwarded herewith.

M S Holcomb

M. S. HOLCOMB
Vice Admiral, U.S. Navy
Director, Navy Program Planning

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System Planning Corp., (Attn: Mr. Fagan)
1500 Wilson Blvd., Arlington, VA 22209
Lockheed Missiles & Space Co., Inc., (Attn: Mr. Drake)
1111 Lockheed Way, Sunnyvale, CA 94086
Defense Technical Information Center (2 copies)
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SYSTEM PLANNING CORPORATION
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AN ASSESSMENT OF SMALL SUBMARINES AND ENCAPSULATION OF BALLISTIC MISSILES — PHASE I

~~UNCLASSIFIED VERSION~~

EXECUTIVE SUMMARY

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This document presents an unclassified version of the Executive Summary from SPC Final Report 554 entitled An Assessment of Small Submarines and Encapsulation of Ballistic Missiles--Phase I (U). This report documented the results of a classified study performed by System Planning Corporation (study director), the Naval Sea Systems Command, and Lockheed Missiles and Space Company for the Chief of Naval Operations. The unclassified Executive Summary is intended only to familiarize the reader with the major findings and results of the three-volume classified report and thus does not reflect the full spectrum of technical matters detailed in the classified report.

EXECUTIVE SUMMARY

A. PURPOSE

In December 1978, the Deputy Under Secretary of Defense for Research and Engineering (Strategic and Space Systems) released funds to the Navy from the SSBN(X) Program for the evaluation of SSBNs and small submarines with external encapsulated ballistic missiles. The evaluation, under the direction of the Chief of Naval Operations (OP-02), is divided into two phases. Phase I assesses the technical feasibility of building and deploying small submarines with external encapsulated MX missiles as an alternative mode of basing for the MX ICBM. Phase II assesses the feasibility of building and deploying SSBNs with external encapsulated missiles as an adjunct or follow-on to the TRIDENT class SSBN. This document reports the analyses and findings of Phase I of the study.

B. BACKGROUND

The development of an advanced ICBM weapon system has been an ongoing effort since about 1971. Approval to proceed with full-scale engineering development of the MX missile was granted in June 1979, and a basing mode for the system was approved for full-scale development in September. However, there is still considerable interest in an examination of the sea-based option.

The currently approved basing mode for MX, called the Horizontal-Dash MX (HDMX) system, would consist of a force of 200 MX missiles deployed in a series of valleys in Nevada and Utah on 200 racetrack-type networks, with one missile per network. Each network would consist of a road with 23 horizontal shelters located on spurs around the track. These shelters would be located about 7,000 ft apart, hardened to approximately 600 psi, and have openable roofs for verification purposes.

The missile would be moved around the track on a transporter-erector-launcher (TEL). Because of its size and weight (180 ft long, 670,000 lb), the TEL would be restricted to operations on the track. Racetracks would not be interconnected, and the TEL could not move between tracks.

The survivability of the system is based on two independent modes of operation. First, the TEL would be moved periodically from one shelter to another. To disguise the movement of the TEL, a shield vehicle would be used to cover the TEL. This shield vehicle would make repeated trips between shelters and simulate the TEL movement procedures. The actual TEL would be moved only occasionally. Second, the mobility of the TEL would be such that it could "dash on warning" to allow repositioning of a portion of the force within the flight time of attacking ICBMs or could be placed in constant motion and then enter the nearest shelter upon warning of an attack.

It is estimated that for this MX basing mode about 50 percent of the system would survive the projected Soviet threat of the late 1980s, assuming SALT II limitations.

C. SCOPE

As part of the assessment of the feasibility of basing the MX missile at sea on small submarines, the following specific objectives [Ref. 1] were to be met:

- Develop an operational concept for deployment
- Assess the technical feasibility of building and deploying
- Develop a concept for logistics support
- Assess survivability
- Provide estimates of cost, schedules, and risks.

In addition to the above objectives, the study addresses the feasibility of the submarine size and logistics support proposed for the Shallow Underwater Mobile (SUM) system concept [Refs. 2 and 3]. In this concept, small conventionally powered submarines with encapsulated MX missiles would operate within several hundred miles of the east and west coasts of the continental U.S. and would be supported logistically from many ports within the U.S. or from sea-going supply and support tenders. In the SUM concept, the small submarines would be modest and economical, typically weigh less than 1,000 tons, have a crew of 12, and carry two encapsulated MX missiles, each weighing about 200 tons.

The study also compares the cost of building small submarines with the cost of TRIDENT class SSBNs to show the economics of small submarine systems versus large SSBNs.

D. DESCRIPTION OF SYSTEM

1. Formulation of Operational Concepts

In developing operational concepts for the small submarines, different submarine areas of deployment, modes of operation, and logistics support concepts were considered.

Three primary submarine deployment areas were analyzed: (1) deployment in the Great Lakes, (2) deployment on the continental shelf in a bottom-sitting, closely tethered to the bottom, or mobile mode, and (3) deployment in the open ocean out to a certain distance from the U.S.

Deployment of the total force of submarines in the Great Lakes was not considered attractive because of vulnerability to a barrage attack of nuclear weapons and the icing conditions of the Great Lakes during the winter.

Deployment of the total force of submarines on the continental shelf appears to offer no significant advantages compared to deployment in the open ocean and has several significant drawbacks. First, the continental shelf of the U.S., which covers approximately 100,000 nmi^2, is a relatively small area in which to constrain the operations of a total force of submarines. Further, the creation of very large waves on the continental shelf by detonation of high-yield nuclear weapons in deep water off the shelf could threaten the submarines deployed there. Although the submarines could have warning on the order of 1 to 2 hr before the waves reached the shelf and they might be able to leave the shelf or be ordered to fire their missiles under warning, such a threat is still a matter for concern.

Both in-port and at-sea logistics support of the submarines were examined. Since it is infeasible to exchange 180-ton encapsulated missiles at sea on an operational basis, in-port support was deemed necessary. Also, since a fraction of the encapsulated missiles would fail per month, frequent capsule changes would be required by the submarines at dedicated port facilities which meet explosives-handling safety requirements. The combination of infeasibility of at-sea support and the safety requirements militates against the logistics support scheme proposed by the SUM proponents (i.e., logistics support provided by sea-going tenders or at many U.S. ports).

2. General Operational Concept

The baseline strategic system would consist of a force of 50 small diesel-powered submarines carrying external encapsulated MX missiles. This system would be capable of performing the same mission as the land-based MX system. These submarines would deploy from dedicated ports in Alaska and on the east and west coasts of the United States. Possible basing sites for submarines are Anchorage, Alaska; Prudence Island, Narragansett Bay, Rhode Island; and Miller Peninsula, Washington. The submarines would patrol for 30 to 60 days[1] and return to port for logistics support and refit.

The submarines would operate out as far as 1,000 nmi from port. They would employ minimal installed navigation equipment and use periodic Global Positioning System (GPS) fixes for positional updates. Missile system accuracy would be achieved by a GPS or Inverted GPS (IGPS) fix during missile flight or, if these systems were inoperative, by positioning the submarine at presurveyed sites in the ocean. Specific details relating to the operational employment of the submarines are classified and are given in Reference 4.

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[1] Depending upon in-port refit time. The submarine would be designed to achieve an at-sea factor of approximately 60 percent.

3. Submarine Description

The principal submarine variant considered is diesel powered and carries encapsulated MX missiles. The hull characteristics of the submarine are: length, 232 ft; beam, 44 ft; and draft, 14 ft. The displacement of the submarine with the missiles is approximately 2,981 tons (surface) and 3,708 tons (submerged).

The submarine consists of a 20-ft-diameter internally framed cylindrical pressure hull with hemispherical end caps. The total length of the pressure hull is 183 ft, with 116 ft devoted to the operations compartment and 67 ft to the engine room. The missile capsules are located port and starboard outboard of the pressure hull and supported by foundations integral with the tank top of the outboard ballast and fuel tanks.

The submarine would have a crew of 45.

4. Missile/Capsule Description

The 92-inch-diameter MX missile would be modified and encapsulated. The capsule would consist of a 1.4-inch-thick cylindrical shell (HY80 steel) with hemispherical end caps. It would be approximately 80 ft long, 10 ft in diameter, have a displacement of 180 tons, and be positively buoyant.

The capsule would provide missile environmental control and shock mitigation for environments resulting from nuclear bursts. Devices to initiate events for missile launch would also be contained in the capsule. Electrical power to the capsule and data transmission to the missile would be accomplished by use of an external umbilical cable.

On the launch command, the capsule would be released from the submarine and would rotate towards vertical while rising. Upon sensing broach of the surface, the top hemisphere and a portion of the lower hemisphere would be jettisoned, the missile would be ignited, and the thrust of the first-stage motor would eject the missile from the capsule.

E. FINDINGS

The principal study findings related to the system and its components are as follows.

1. System Feasibility

It appears technically feasible to build, deploy, and logistically support small submarines with encapsulated ballistic missiles; however, many technical problems remain for resolution.

No technical areas have been identified which would clearly preclude the achievement of the concept. There are many significant areas of technical uncertainty associated with the baseline system concept.

The principal areas of concern are:

- The degree of modification to the land-based MX missile required for use in this basing mode needs to be defined. An assessment of the modifications to the MX missile can be made only after a firm MX design definition and a very mature definition of the encapsulated missile submarine system. Requalification of the MX missile for underwater deployment could vary from a few flight tests with minor equipment and software mods to major redevelopment approaching a significant fraction of MX development.
- Assessments of system accuracy attainable throughout the total spectrum of launch scenarios are categorized as estimates. Significant analysis would be required to develop a more accurate assessment of achievable system accuracy.
- The reliability of multiple capsule launch and the possibility of the submarine being struck by the expended capsule after missile launch from an immobile or slowly moving submarine are serious matters of concern. To solve these problems, several schemes are possible; however, a proper solution would require a system trade-off study.
- There is a great deal of uncertainty concerning the underwater nuclear shock environment and the appropriate design criteria to be used for the ship-to-capsule and capsule-to-missile shock specifications. Definition of missile/capsule shock mitigation requirements and translation into a foundation and launching design has only been analyzed in gross terms. This is an area of significant risk, whose solution would take into account factors such as practical attachment tolerances, capsule-to-ship handling provisions, and the uncertainty in the shock environment.

- Methods, equipment, facilities, and ship interfaces required to safely and reliably on-load and off-load the large capsules would need to be devised. One conceptual method of handling the large, heavy capsule would be to use a large bridge crane with related capsule and ship handling equipment. Alternative methods, such as floating the capsule into place (with or without a crane to assist, and with or without a drydock), remain to be evaluated.
- Selection of sites and acquisition of land for the dedicated shore-based facilities is an area of concern.

Achievement of approximate land-based MX accuracy appears feasible under operational constraints.

Table 1 summarizes five operational modes in which high weapon system accuracy could be achieved. The first four modes listed assume that the submarine would employ minimal installed navigation equipment (MK 27 gyrocompass, velocity measuring sonar, and navigation plotter) and obtain periodic Global Positioning System fixes for positional updates. In the first two operational modes listed in the table, the submarine would either bottom sit or anchor close to the bottom at presurveyed positions on the continental shelf. In the third mode listed in the table (mobile with GPS or IGPS), the missile would obtain either a GPS fix or IGPS fix in post-boost flight. The use of IGPS, which could be deployed along the coast of CONUS and Alaska as well as inland, would limit the operational area from which missiles could be launched to allow receipt of four IGPS stations. If GPS or IGPS was not available (mobile without GPS or IGPS), then relatively high weapon system accuracy could still be achieved if a highly accurate submarine position fix was obtained during missile launch preparation, as would be possible at presurveyed positions in the ocean. The last entry in the table assumes that the submarine uses the MX missile Advanced Inertial Reference Sphere (AIRS) guidance for precise ship navigation. The table cites approximate systems accuracy relative to that of land-based MX at maximum launch range. At the shorter launch ranges possible with this concept (e.g., launch from the Gulf of Alaska), system accuracy would be better than at maximum range.

TABLE 1. STRATEGIC WEAPON SYSTEM ACCURACY

Operational Mode	Conditions	Approximate Accuracy
Bottom Sitting	Geographic and gravity data available (quality high-frequency data known within 200 nmi radius of launch point) AIRS gyrocompassing (approximately 12 hr required for initial calibration) MX computational techniques optimized for this system Launch position (latitude and longitude) error no greater than 30 ft	Land-based MX times 1.3 to 1.5
Bottom Anchored	Same as above plus velocity measuring sonar (VMS)	Land-based MX times 1.4 to 1.5
Mobile With GPS or IGPS	MX missile and guidance modified as necessary (add antennas, receiver, mod computer, and power source) Operational area limited to allow post-boost "look" at four stations (IGPS) Quality IGPS or GPS data receipt AIRS gyrocompassing	Similar to land-based MX
Mobile Without GPS or IGPS	Submarine position fix during launch preparation AIRS gyrocompassing Velocity measuring sonar (VMS)	Land-based MX times 1.4 to 1.5[a]
Mobile Without GPS or IGPS, Using Missile Guidance and VMS for Navigation	Position reset within 16 hr prelaunch Additional MX modifications and development required Requires additional 1,200 ft^3 ship's volume, 6 tons weight, 5 kW power, and 8 crew personnel	Land-based MX times 2[a]

[a]Results based on brief analysis.

2. Submarine

A diesel-powered submarine with a pressure hull 183 ft long, 20 ft in diameter, and displacing 1,614 tons (for the pressure hull only, exclusive of all external structure) was estimated to be the smallest achievable to provide the required speed, endurance, and missile support functions.

The submarine with the capsules and necessary supporting and other structure external to the pressure hull would have surface and submerged displacements of 2,981 tons and 3,708 tons, respectively. This finding is at variance with the SUM concept of employing small submarines of 1,000 tons or less. There is concern regarding how much greater the submerged displacement of the smallest achievable diesel-powered submarine was calculated to be compared to that originally postulated in the SUM concept. This fact alone exemplifies, to some extent, the potential impact of further development of areas containing many unknowns.

3. Missile/Capsule

There were no areas identified which could technically preclude the encapsulation of an MX missile or deny a potential for useful mission performance characteristics.

However, many areas of systems tradeoffs remain to be resolved before any confident statements of systems performance, development risk, and programmatic issues can be made.

Modification of the MX missile for application to this concept would be required.

A confident assessment of the MX missile modification for this system concept application would require firm MX design definition, a very mature definition of this system, and comprehensive system evaluations. However, several representative examples of potential modification were identified:

- A new, shorter nose shroud to minimize capsule length
- Addition of GPS or IGPS equipment
- Guidance computational methods and software to accommodate operational scenarios

- Hardware redesign or requalification to meet this system concept's unique conditions; e.g., launch and stowage environments and first-stage motor ignition logic.

4. Submarine Survivability

A force of submarines deployed in the Great Lakes would not be very survivable against a massive nuclear barrage attack.

The barrage attack consists of the projected Soviet threat against the MX system. The submarines were assumed deployed in the three largest of the Great Lakes--Superior, Michigan, and Huron. Lake Erie has very little area with a water depth of 30 fathoms or greater, and it almost completely freezes over during the course of a normal winter. Lake Ontario, which represents about 8 percent of the area of the Great Lakes, would probably be inaccessible from the three largest lakes during certain times in the winter due to the freezing of Lake Erie.

The creation of very large breaking waves on the continental shelf of the U.S. (Van Dorn Effect) by the detonation of high-yield nuclear weapons in deep water off the shelf could threaten a force of submarines deployed there.

Although the submarines could have warning on the order of 1 to 2 hours and might be able to flee the shelf or be ordered to fire their weapons, such a threat is still a matter of concern. The Van Dorn Effect has been predicted by theory and confirmed by tank tests; however, it has never been confirmed on a large scale.

In water that supports the formation of convergence zones (CZs) and long-range acoustic propagation, the diesel-powered submarines could be vulnerable to detection and tracking by high-gain towed arrays; however, if the submarines are optimally deployed and make use of water that does not support CZ formation, then high-gain towed arrays would not pose a significant threat.

In the total area analyzed for deployment of submarines, CZ formation would not be supported in about 40 percent of the area during summer and in about 20 percent of the area during winter. With the submarines optimally distributed between these CZ and non-CZ regions, force survivability would be relatively high against a massive nuclear barrage that was targeted based on tracking by high-gain arrays. This result is based on the conservative assumptions that (1) the submarines are uniquely identifiable, which permits array crossfixing, (2) there are no false contacts or degraded array system performance, and (3) the submarines do not make use of intelligence information to avoid the arrays.

Of the nonacoustic sensors examined, satellite and airborne radar appeared to pose the greatest threat against the diesel-powered submarine; however, relatively high submarine force survivability is believed achievable.

The threat consisted of radar detection of the submarines while snorkeling, followed by a massive barrage attack of the areas believed to contain the submarines. Against a radar search supported by long-range ASW aircraft, a relatively high fraction of the submarine force could be expected to survive. Satellite-borne synthetic aperture radar has the potential for frequent detection of the diesel-powered submarines; however, if the submarines made use of intelligence on satellite scans of the operating area and planned their snorkel operations accordingly, and/or if numerous radar reflectors that could simulate a snorkeling submarine were seeded in the operating area, then the threat posed by satellite-borne radar would be very limited.

5. System Cost

The total life-cycle cost estimates of the encapsulated missile submarine system, including full-scale engineering development (beginning with DSARC Milestone II), production (beginning with DSARC Milestone III), deployment operation and support (beginning with IOC, ending at FOC), and steady-state operation and support (10 years of operations beginning with FOC), range from $33.1 to $46.5 billion (FY80 dollars), with an average cost of $39.8 billion.

Table 2 presents a summary of the baseline system costs; these are rough-order-of-magnitude estimates.

TABLE 2. SUMMARY COST TABLE--BASELINE CASE

	Quantity	Cost[a] of Baseline System ($B, FY80) RDT&E	Investment	O&S	Totals
Submarines	50	0.4-0.7	6.3-7.8	5.2-7.0	11.9-11.5
Missiles	465	1.2-1.6	7.8-8.6	0.3-0.4	9.3-10.6
Strategic Weapon System	50	0.3-0.4	0.6-2.3	0.5-2.0	1.4-4.7
Capsules	500	0.2-0.3	2.5-3.6	0.7-1.1	3.4-5.0
Navigation Aids	1,000-2,000[b] 3,000[c]	0.1-0.1	0.9-1.8	0.8-1.6	1.8-3.5
Bases	3	-	5.3-7.2	-	5.3-7.2
Totals		2.2-3.1	23.4-31.3	7.5-12.1	33.1-46.5
Average		2.6	27.4	9.8	39.8

[a]Costs given range from low nominal to high nominal

[b]1,000-2,000 IGPS stations

[c]3,000 bottom transponders

The baseline system consists of 50 submarines. It would take a total force of about 50 submarines to support approximately 30 submarines on station that would be capable (assuming 100 percent survivability and a 60 percent at-sea factor) of delivering the required number of reentry vehicles (RVs) on target. Of the 465 MX missiles costed in this study, 200 are operational missiles for the submarine force; 200 missiles are for operational tests (OT) and follow-on operational tests (FOT) (20 per year for 10 years); 50 missiles are for demonstration and shakedown operations (DASO) (one per ship at initial deployment); and 15 missiles are included for the Fleet Readiness Evaluation Program (FREP). There is one strategic weapon system for each submarine. Of the 500 capsules, there is one capsule for each tactical, OT/FOT, and DASO missile. In addition, there is a capsule for each submarine which is used for DASO at the end of each ship's first overhaul. There are no FREP capsules.

The navigation aids consist of 1,000 to 2,000 IGPS stations and 3,000 transponders; these are adequate for the deployment area under consideration. In the baseline case, a three-base deployment was postulated, one base each in Alaska and the northwest and northeast areas of the 48 contiguous states.

The total system acquisition (RDT&E plus investment) and life-cycle costs for other than the baseline buy of 50 submarines are presented in Figure 1. More than 50 submarines would be required for less than 100 percent survivability or for lower than a 60-percent submarine at-sea factor.

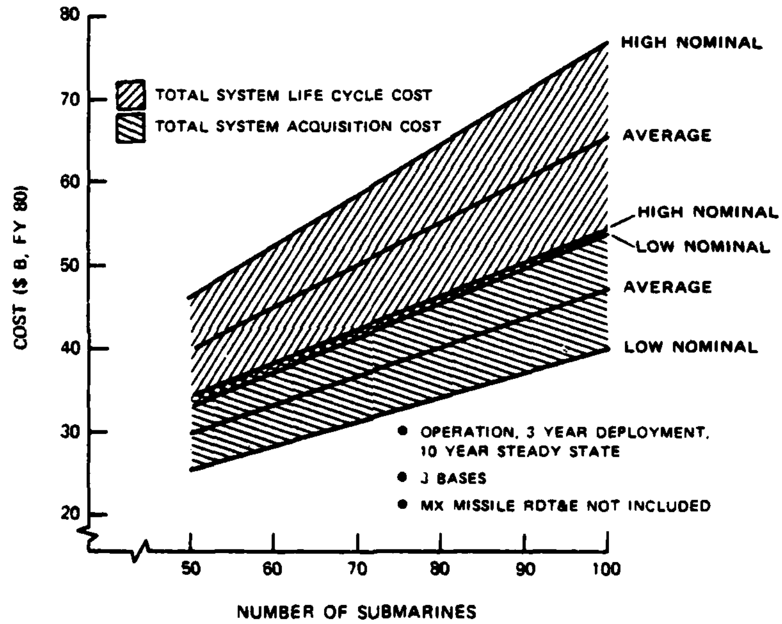

FIGURE 1. SYSTEM LIFE CYCLE COST AND ACQUISITION COST VERSUS NUMBER OF SUBMARINES

Total acquisition (RDT&E plus investment) costs for the baseline encapsulated missile submarine system and the land-based MX system are about equal.

The program cost for MX is currently being estimated by DoD at $33.8 billion. However, this cost does not include operation and support (O&S). It does, however, include $5.5 billion for MX missile development, which is required but not included in the encapsulated missile program.

Based on the average cost presented in Table 2, the $5.5 billion land-based missile development cost is added to the $2.6 billion encapsulated missile system development cost to bring the RDT&E phase costs into consistency. Then, the $27.4 billion investment cost is added to arrive at an acquisition (RDT&E plus investment) cost of $35.5 billion. This is the value to compare with the land-based system acquisition cost of $33.8 billion. The 5-percent difference in these figures is much smaller than the range of estimates for the encapsulated missile submarine system acquisition costs ($31.1 to $39.9 billion, or $\pm$12 percent).

It should be noted that there are many more missiles in the sea-based system than in the land-based one (465 versus 330). Both systems have the same 200 operational missiles. The greatest difference lies in the number of test and shakedown missiles--250 for the sea-based system versus 108 for the land-based system. The remaining missiles are for spares, pipeline, and reliability testing purposes. The difference (135) in number of missiles (465 for sea based versus 330 for land based) accounts for some $2.4 billion in the total cost of the sea-based system.

<u>The encapsulated missile submarine system costs per missile at-sea appear higher than the same costs for TRIDENT class SSBNS</u>.

On a cost-per-missile-at-sea basis, the acquisition and 25-year life cycle costs for the baseline encapsulated missile submarine system are approximately $295 million and $475 million, respectively, assuming a 60 percent at-sea factor. The same costs for a force of 16 TRIDENT submarines carrying TRIDENT II missiles are approximately $155 million and $230 million, respectively, assuming a 66 percent at-sea factor.

6. Schedule

<u>The Initial Operational Capability (IOC) of the system is estimated to be achievable by 1992, with Final Operational Capability (FOC) to follow in 3 years</u>.

The system IOC is driven by submarine base availability. The estimate of a 1992 IOC assumes that site selection, preparation of environmental impact statements, and subsequent military construction would proceed at a pace similar to that of the TRIDENT bases. An IOC might be achieved 1 or 2 years earlier if the program was pursued under highest national priority.

It should be noted that there is a 6-year time lag between the first flight test of the Air Force land-based MX missile and the first flight test of the sea-based MX system. The time lag between the Air Force development of the MX missile and the completion of the modifications necessary to adapt it to an underwater basing mode could result in additional costs for the sea-based system.

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3. SRI International, JASON Study Group, Alternative Basing (U), JSR-78-02, March 1979, SECRET.

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

The U.S. system of units rather than the metric system was used throughout this summary at the request of the Contracting Officer's Technical Representative (COTR) and for the convenience of the reader. A conversion table is provided below.

CONVERSION TABLE

1 in	=	2.54 cm
1 ft	=	.3048 m
1 yd	=	.9144 m
1 nmi	=	1.852 km
1 fathom	=	1.829 m
1 acre	=	4.046 km^2
1 lb	=	.4536 kg
1 ton (long)	=	1,016 kg
1 nmi^2	=	3.43 km^2
1 ft^3	=	.0283 m^3
1 kn	=	1.852 km/hr
1 ft/sec	=	.3048 m/sec

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