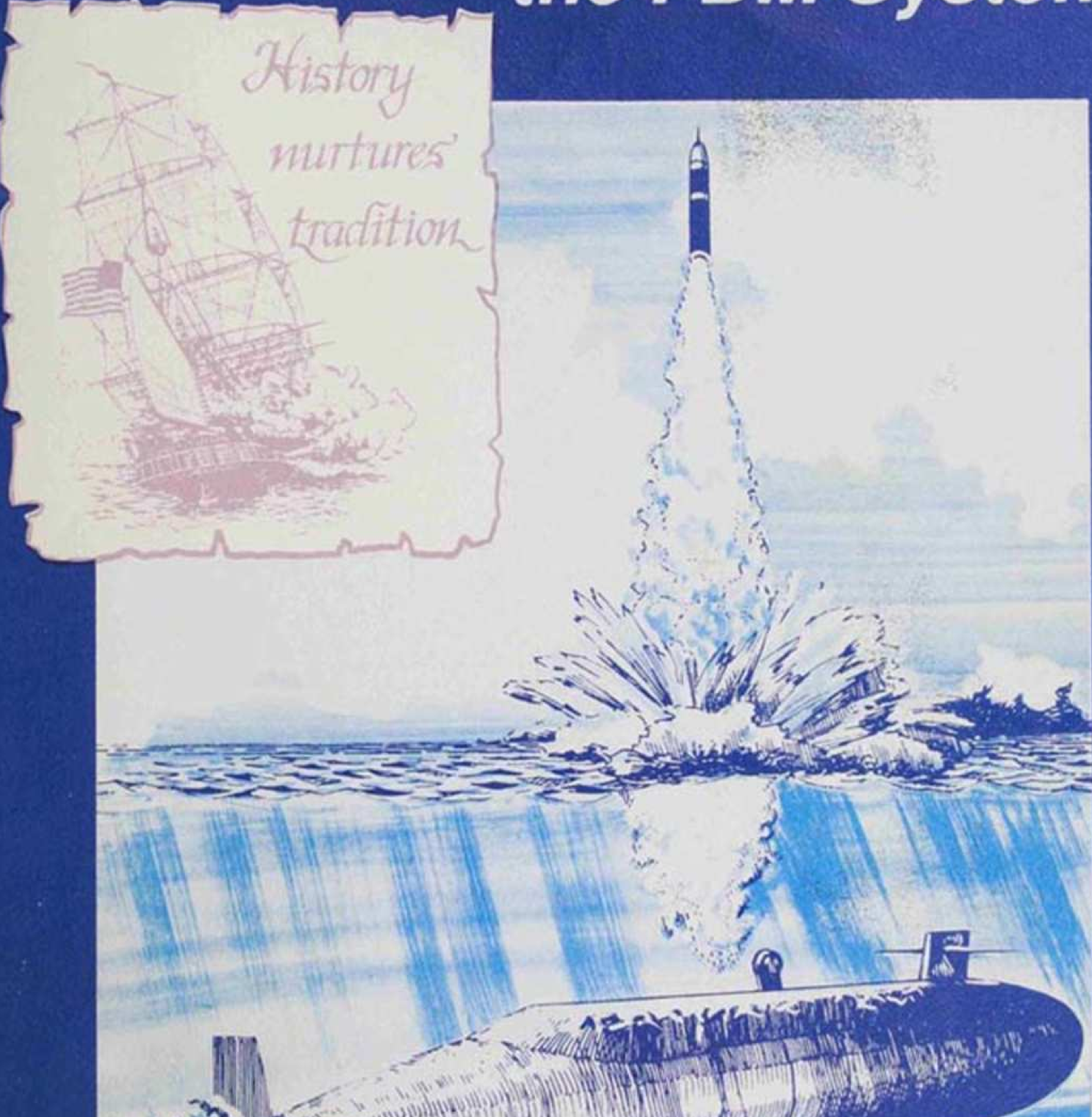
A History of the FBM System



Lockheed Missiles & Space Company, Inc.

Howard Burst

INTRODUCTION

There have been several historical documents written over the course of the years on the U.S. Navy's Fleet Ballistic Missile (FBM) System. This report is not an attempt to reinvent the wheel. It is intended to be a gathering of important FBM facts in one place. It will be divided by time spans, related to a missile system, briefly describing what went on during the indicated time span followed by a list of important dates and events as we step through the years.

The MSD documents **POLARIS Development Highlights (1956 - 1964)**, reference (1), and **Highlights of the POLARIS Engineering and Manufacturing Effort** (July 1964 - July 1968), reference (2), in addition to providing historical highlights of the FBM Program also contained a historical listing of organizations/personnel of Lockheed Missiles and Space Company, Inc. (LMSC)/Missile Systems Division's (MSD).

MSD has originated a document which, starting with the listing of references (1) and (2), provides subsequent listings of organizations/personnel as the various FBM programs evolved in MSD. This document, **Organizational Highlights of the Missile Systems Division (1956 - 1983)**, dated January 1984, reference (21), is to be updated. The listings therein are too voluminous to be included in this **A History of the FBM System**.

Section F of this document, FBM Weapon System Summary; provides a condensed "snapshot" history of the FBM System.

J. P. McManus

J. P. McManus
1989

DOWNGRADED AT 3 YEAR INTERVALS
DECLASSIFIED AFTER 12 YEARS
DOD DIR 5200.10

TOP SECRET
SECRET
DECLASSIFIED.

00 Pers. file

2 December 1955

MEMORANDUM FOR: Rear Admiral Clark (Op-51)
Rear Admiral Raborn (Office of the Secretary of the Navy)

Subj: ICBM - IRBM

1. It is quite evident that we must move fast on this fleet ballistic missile and that our present schedules for shipboard launching are not good enough. I think that the first service that demonstrates a capability for this is very likely to continue the project and the others may very well drop out. This missile must be fired from a ship just as early as possible even though the equipment in the ships is not as desirable as can be conceived. For example, the equipment for the location of a ship need not be too accurate for the test firing. The launching could take place from the vicinity of Banana River where the ship can be located exactly.

2. In view of the fact that the President wants a report monthly I, of course, will want a report weekly and, like the President, I will want it to be a progress report.

3. If Rear Admiral Raborn runs into any difficulty with which I can help, I will want to know about it at once along with his recommended course of action for me to take. If more money is needed, we will get it. If he needs more people, those people will be ordered in. If there is anything that slows this project up beyond the capacity of the Navy Department we will immediately take it to the highest level and not work our way up through several days. In taking this type of action we must be reasonably sure we are right and at least know the possible consequences of being wrong because we will be disrupting many other programs in order to make achievement in this one if we are not careful. That is all right if we really make an achievement.

SECRET
TOP SECRET
DECLASSIFIED

Page 1 of 2 pages   Copy No. 10 of 10 Copies

FILE COPY

OPNAV FORM-5000-1 (REV. 5-53)

TOP SECRET

DECLASSIFIED

4. The Air Force has got a tremendous amount of enthusiasm which they demonstrate behind their project and we must have even more. The awards should be made to companies as soon as possible and our major contract awards, I think, should be made by the 15th of December.

5. The next report on this should be made by somebody who is enthusiastic, who gives evidence of his enthusiasm, and whose knowledge demonstrates that he has a thorough grasp of the problem and is pushing ahead just a little bit faster than anybody else could.

ARLEIGH BURKE

Copy to:
Op-09
All Deputies

DISTRIBUTION:

Copy #1 ADM CLARK
Copy #2 ADM RABORN
Copy #3 Op-09
Copy #4 Op-01
Copy #5 Op-02
Copy #6 Op-03
Copy #7 Op-04
Copy #8 Op-05
Copy #9 Op-06
Copy #10 - Green

Per JH

RADM CLEXTON E.W.

TOP SECRET

TOP SECRET

DECLASSIFIED

CONTENTS

A STAR IS BORN — POLARIS (1955 - 1960)

World War II, the Berlin Airlift, and the Korean conflict were behind us and the world was at peace. Or was it?

The Soviet Union was making rapid strides in nuclear development. The United States (U.S.) Intercontinental Ballistic Missile (ICBM) seemed to be facing problems in propulsion, guidance and reentry. The armed services had been assigned separate roles in nuclear warfare (conforming to the 1948 "Key West Agreement"). The ICBM had been assigned to the Air Force. The Army was authorized to develop a 1500 nm intermediate range ballistic missile (IRBM). The Navy had no defined role.

In the summer of 1955, a committee appointed by President Eisenhower and chaired by James R. Killian Jr. of the Massachusetts Institute of Technology (MIT), issued a report on the U.S. defense posture. It, along with a separate National Security Council paper, recommended that a 1500 nm IRBM be considered for both land-basing and sea-basing. Eisenhower agreed and the Navy had a role in the Strategic Missile World. Four missile programs existed. The Air Force had the Atlas ICBM and its backup the Titan plus the Thor (IRBM).

The Army had the JUPITER IRBM. The Navy asked to participate in the Air Force's program but the Air Force discouraged them from doing so; too many changes would be needed for a sea-based IRBM. The Army agreed to the Navy's request to participate.

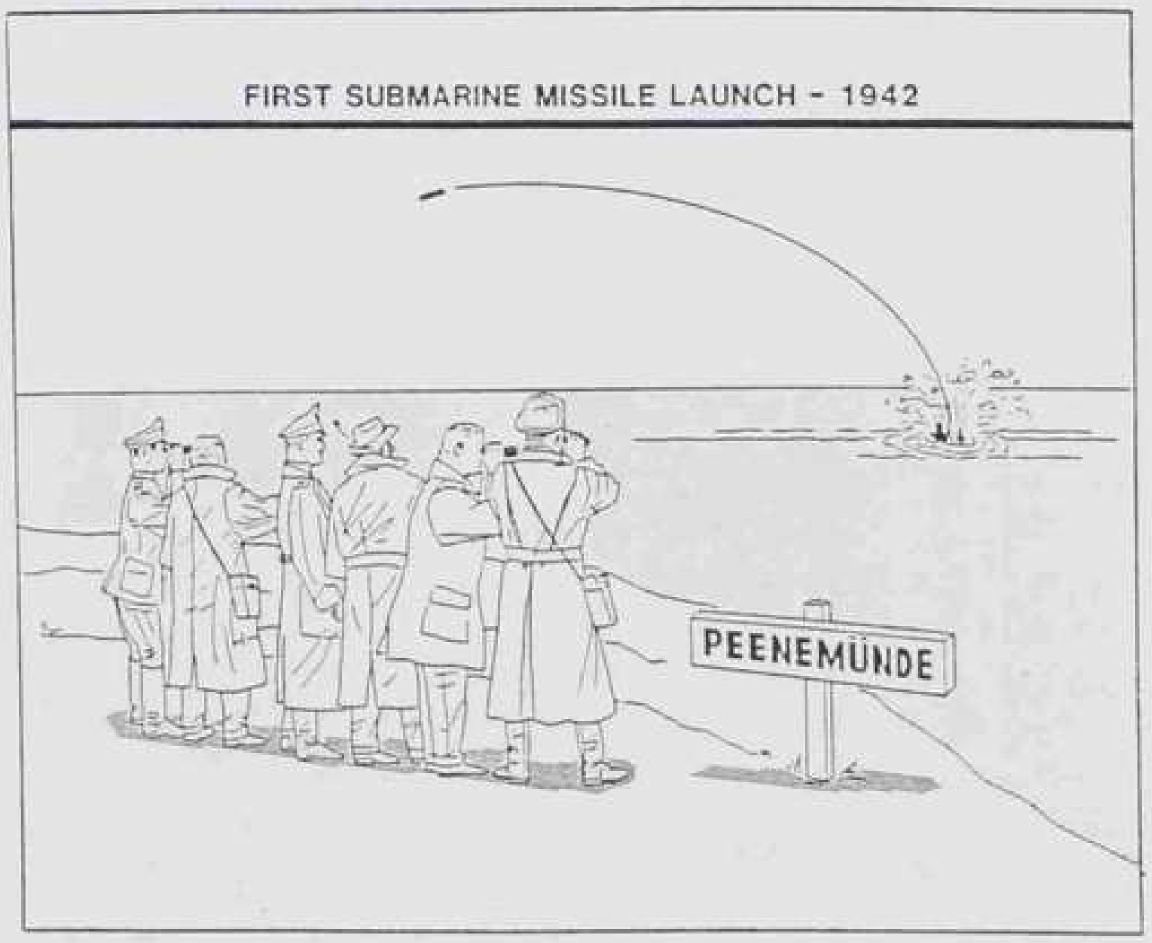
The Secretary of Defense (SECDEF) established, on 9 September 1955, a Joint Army-Navy Ballistic Missile Committee (JANBMC) to proceed with development and adoption of the liquid-propelled JUPITER IRBM for Navy use. The Army was to develop the missile and the Navy was to develop the ship launching system. The Secretary of the Navy (SECNAV) created, on 17 November 1955, a Special Projects Office (SPO).

There was a "tug of war" between the Navy's Bureau of Aeronautics and the Navy's Bureau of Ordnance as to which would be the lead in this effort. The project was given to the Bureau of Ordnance, but the Bureau of Aeronautics was kept happy by the selection of their Rear Admiral (RADM) William F. "Red" Raborn to be the Director, SPO. He reported as Director on 5 December 1955.

It had, as its objective, a ship-based liquid propellant adoption of the Army's JUPITER (IRBM). RADM William F. "Red" Raborn and his SPO was to work with the Army, which had established a similar organization in Huntsville, Alabama, under Major General (MG) Bruce Medaris to develop JUPITER. He had as his chief technical officer, Dr. von Braun (of Peenemunde fame).

SPO worked with the Army for the better part of a year. A cadre of SP officers was established at Huntsville, Alabama, to ensure that Navy requirements levied on the missile's characteristics were understood and were being met by the Army. The Army's initial surface-ship-launched version of the JUPITER was to be available for operational evaluation by January 1960. A submarine-launched version was to be ready for operational evaluation by January 1965. However, the Navy stated "on a long term basis, the Navy proposes a solid propellant development program pointed towards surface ships and eventual submarine use. The solid propellant would alleviate the serious hazards and difficult logistics, handling, and storage problems associated with liquids. The solid propellant is an integral part of a submarine program."

This concept has been attributed to have been derived from a World War II German invention described in some captured Nazi documents taken during the latter part of the war from a captured, high-level German headquarters. The proposal involved the installation of mortar tubes on the deck of a U-boat and the firing of the mortars, while the tubes were still partly submerged, at a land-based target. The proposal had, in fact, been implemented and actual test firings had taken place with an encouraging amount of success.



Peenemunde

In March 1956, the Department of Defense (DoD) approved the Navy's parallel solid-propellant program. Lockheed and Aerojet became involved.

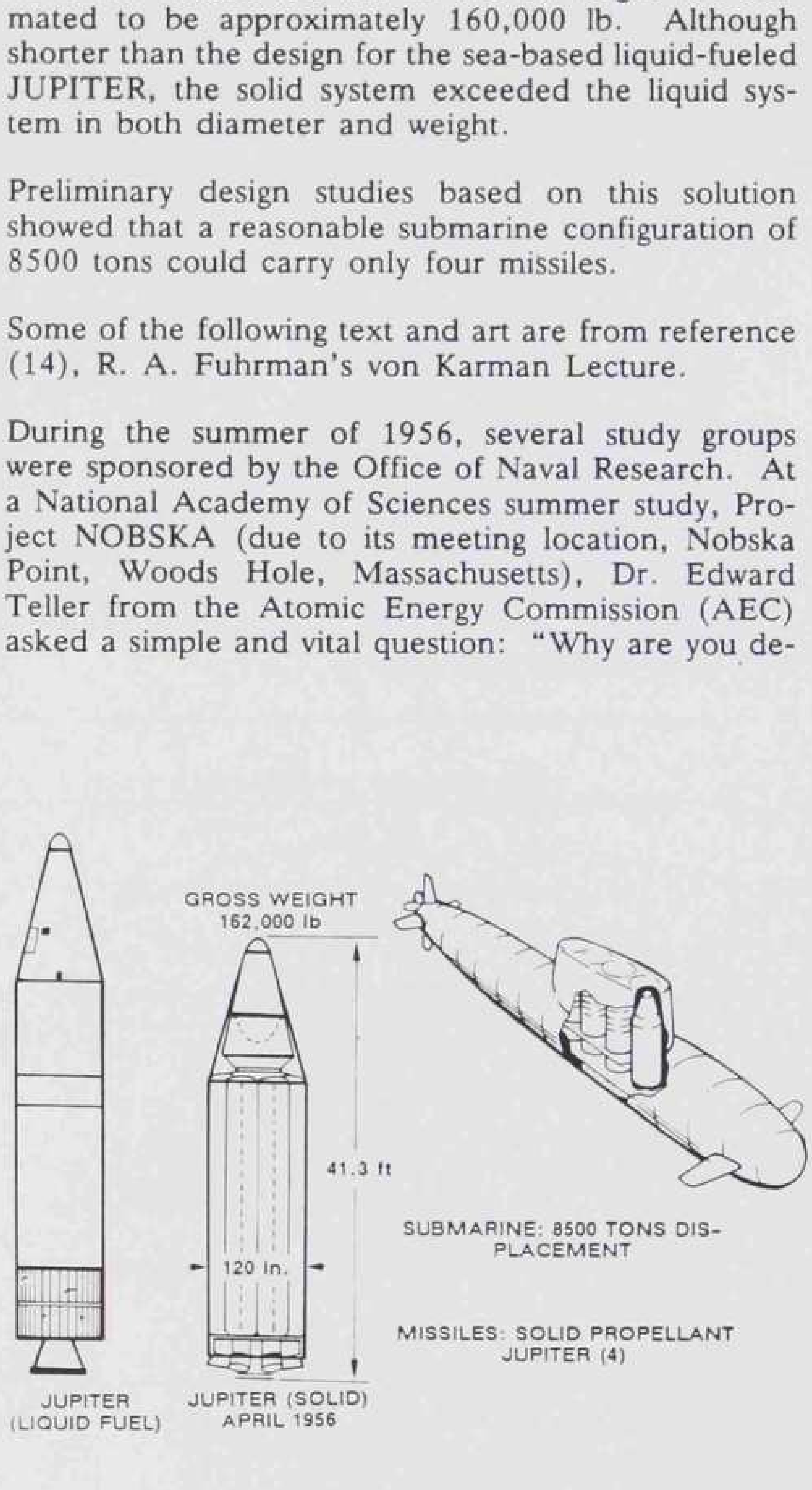
Based on a February 1956 Lockheed proposal to study the feasibility of using solid propellants for a submarine-launched missile, the Strategic Systems Projects Office (SSPO) assigned LMSC the task of investigating the use of solid-propellant motors.

In May 1956, Lockheed proposed a solid-propellant vehicle — "JUPITER-S." In keeping with the state-of-the-art (SOTA) of 1956, it would be a very large missile which would deliver a 3000 lb warhead at a 1500 nm range using a very heavy guidance system. The LMSC concept was a first stage (FS) cluster of six motors, each 40 in. in diameter, surrounding a similar single motor of the same dimensions which served as the second stage (SS). The overall diameter of the missile was 120 in. and its weight was estimated to be approximately 160,000 lb. Although shorter than the design for the sea-based liquid-fueled JUPITER, the solid system exceeded the liquid system in both diameter and weight.

Preliminary design studies based on this solution showed that a reasonable submarine configuration of 8500 tons could carry only four missiles.

Some of the following text and art are from reference (14), R. A. Fuhrman's von Karman Lecture.

During the summer of 1956, several study groups were sponsored by the Office of Naval Research. At a National Academy of Sciences summer study, Project NOBSKA (due to its meeting location, Nobska Point, Woods Hole, Massachusetts), Dr. Edward Teller from the Atomic Energy Commission (AEC) asked a simple and vital question: "Why are you designing a 1965 weapon system with 1958 technology?" He predicted dramatic reductions in warhead weight for an acceptable yield and presented historical data to support those predictions.



Submarine-Based JUPITER Concept

Meanwhile, the MIT Instrumentation Laboratory, under the direction of Dr. Charles Stark Draper, was developing a line of small, lightweight inertial components for missile-borne guidance systems.

Rumbeau and Henderson, two scientists working at Atlantic Research under the sponsorship of the Office of Naval Research, ignored the textbook on the amount of aluminum powder that was permitted in solid propellants. They postulated that the more aluminum powder added, the more the specific impulse would be increased. They put in a massive amount and marked improvement in impulse resulted. This indicated that it would be possible to build large solid-fuel motors for a 1200 to 1500 nm missile.

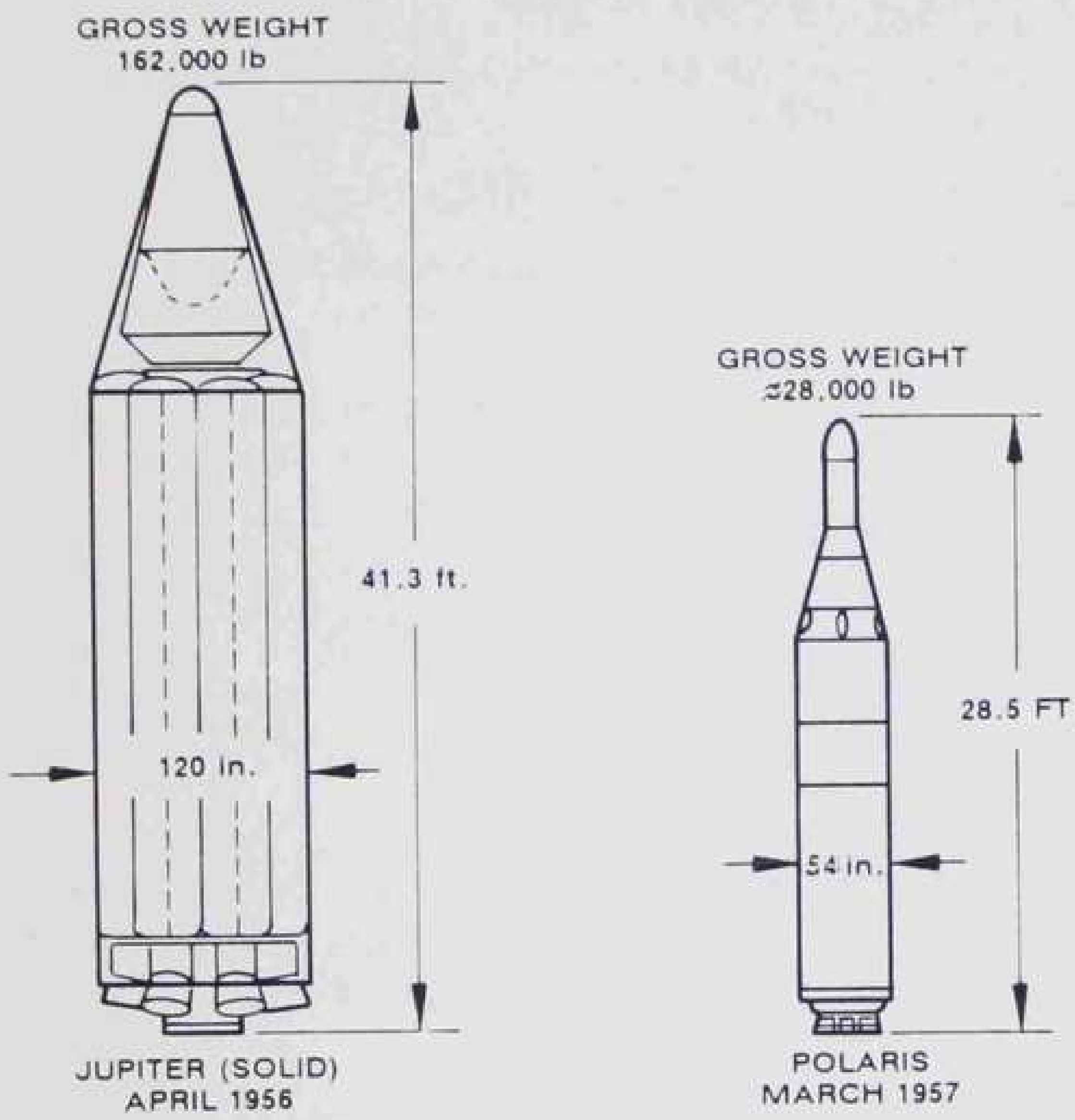
The potential of a warhead, whose weight and volume were a fraction of the JUPITER system, was sufficiently enticing to cause a preliminary missile design to be created by NOBSKA. The weight of an advanced all-inertial guidance system, resulted in a two-stage solid-propellant (NOBSKA) missile configuration in the 30,000 lb class.

Performance projections for this 30,000 lb class missile were provided to the Chief of Navy Operations (CNO), Admiral (ADM) Arleigh A. Burke, on 4 September 1956. ADM Burke requested that the AEC certify the warhead projections of Dr. Teller. In parallel, the SPO was asked to provide, in conjunction with contractor support from Lockheed and Aerojet, an assessment of the missile size and weight. The AEC responded with unconditional support on 27 September. RADM William F. "Red" Raborn presented to CNO the smaller Lockheed-conceived missile, calling it POLARIS. Thus, the name POLARIS for the proposed Navy ship-launched missile was originated officially in September 1956.

The events associated with POLARIS followed in a rapid succession (see List of Milestones at the end of this section). Lockheed submitted a revised design study of POLARIS and also recommended to the Navy that underwater (submarine) launching of POLARIS be considered as the immediate operational mode rather than later (after the ship-launched version).

The SECNAV proposed the POLARIS to the SECDEF and requested deletion of missile launch capability from merchant ship hulls. During the course of this presentation to the SECDEF, RADM William F. "Red" Raborn stated that there would be "saved upwards to $50,000,000" with this concept versus the program presently embarked on. This helped sell the new program.

On 8 December 1956, the SECDEF authorized the Navy to proceed with POLARIS, terminated participation in the liquid JUPITER program, and dissolved the JANBMC. This was the official beginning of the POLARIS development program. The Navy's role of adopting an Army missile to a ship-launched system was changed to developing a completely new missile/weapon system, including the submarine, along with all of the required support.

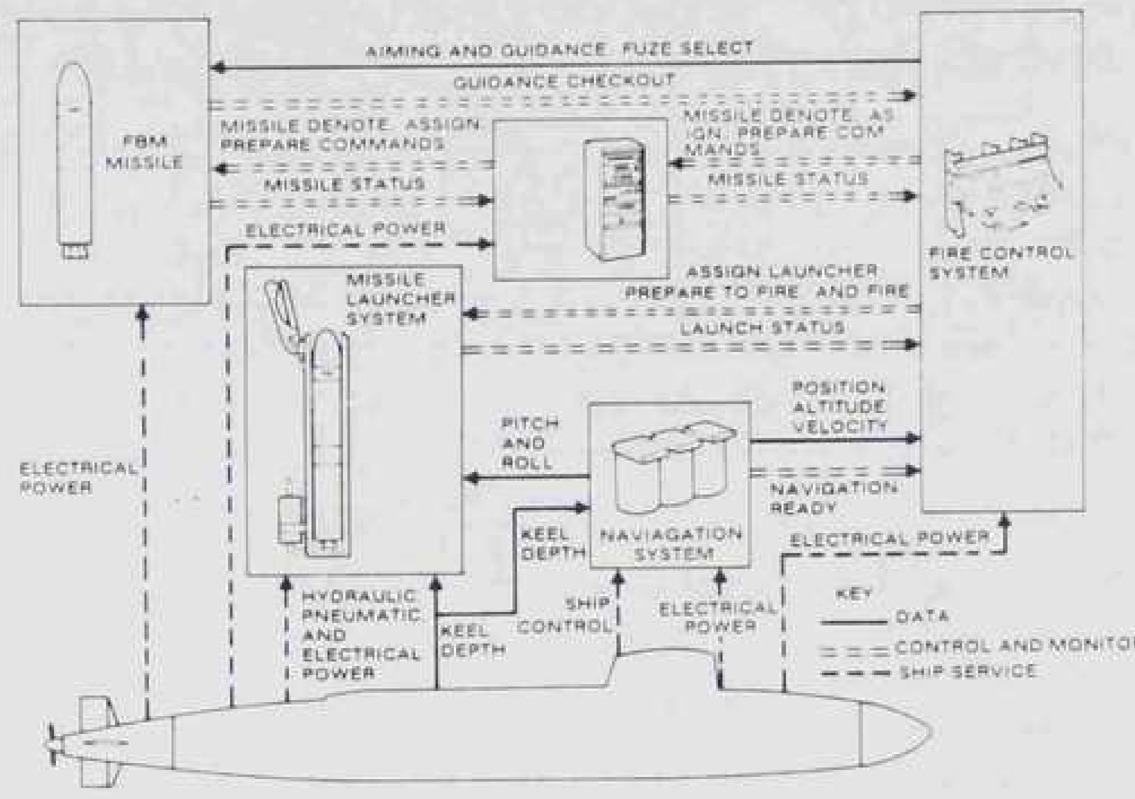


Evolution From JUPITER to POLARIS

Developing all elements of the new weapon system concurrently on a schedule compatible with the new submarine presented a significant program management challenge to RADM William F. "Red" Raborn. It also presented a major technical challenge, calling for early definition and commitment of the various subsystems. RADM William F. "Red" Raborn had brought onboard as his Technical Director, a Captain (CAPT) Grayson Merrill from the Bureau of Aeronautics, a fine technical manager. However, when the changeover from JUPITER to the solid-propellant motored missile came about, steps were initiated to bring CAPT Levering Smith onboard as an assistant technical director. He was an authority on solid propellants. Shortly thereafter, CAPT Merrill decided to retire on his own volition. CAPT Levering Smith became Technical Director.

Functional subsystems of the new weapon system were established to clearly define interfaces which also defined the organizational structure of the SPO. They remain so to this day.

Within the SPO (circa 1957), the technical branches included Launcher, Missile, Fire Control and Guidance, Ship Installation, Navigation, and Operations and Test. SPO's organization and supporting contractor team is basically the same today.



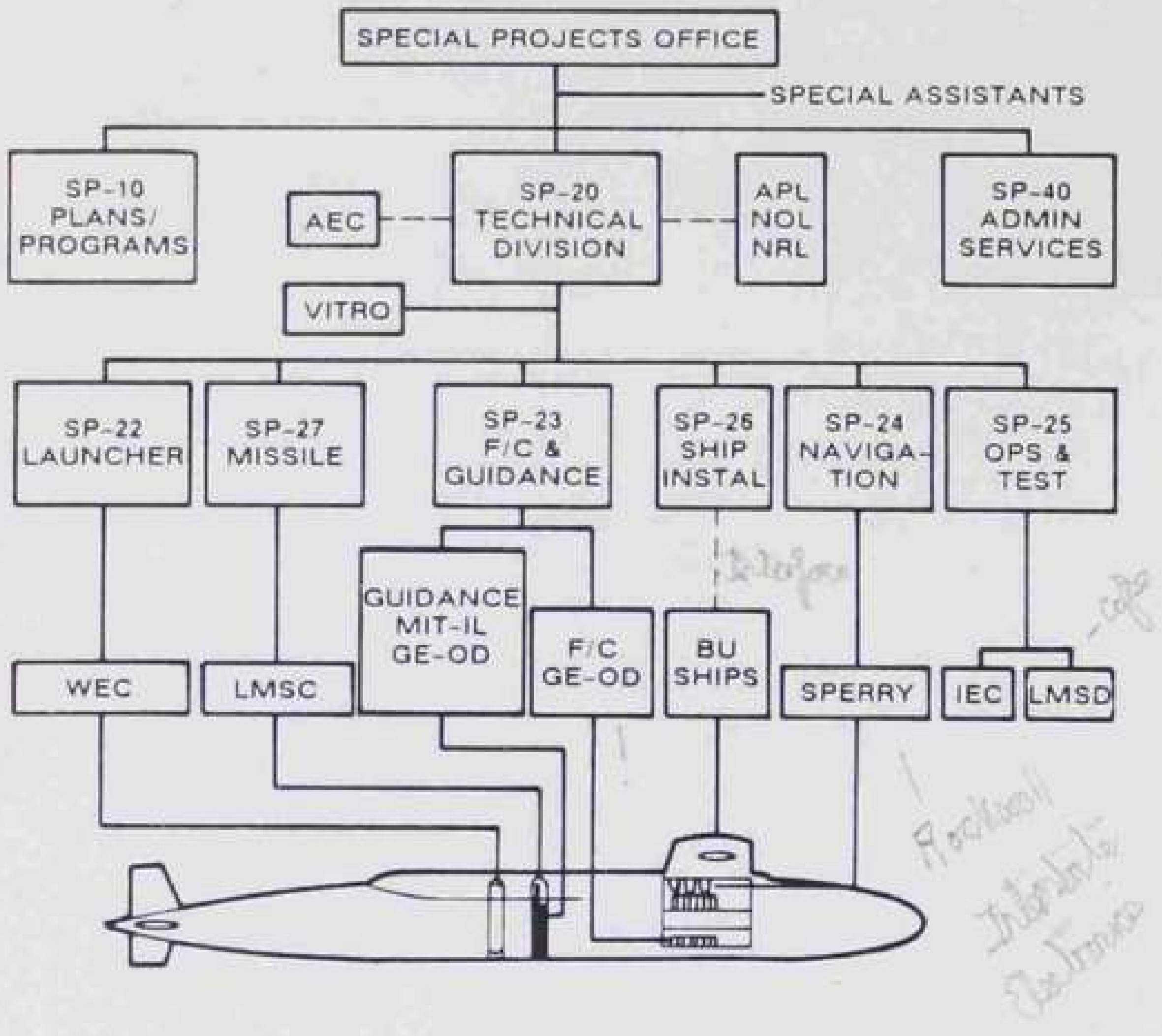
FBM Weapon System Simplified Functional Diagram

The schedule necessitated concurrent development of missile, guidance, navigation, fire control, and launcher. It called for sharply-defined interfaces, and continuing physical-functional interface coordination. Vitro Laboratories provided support to the Chief Engineer of the SPO and played an important role in weapon system interface coordination, system safety, and systems planning. Mr. John B. (Dick) Buescher became the Chief Engineer in the early days of SPO. The Chief Engineer for the entire Missile Weapon System exercised the ultimate authority and responsibility for the technical coordination of all weapon subsystems into a viable operable weapon system and included all engineering aspects from basic engineering development through operational support of deployed weapon systems.

The technical soundness and validity of engineering aspects rested solely on this position. It should be borne in mind that other similar systems within DoD use contractors as systems managers. SP, through the office of the Chief Engineer, functioned as its own systems manager, and still does today.

Mr. Sol Berg provided important support to this function in the system coordination of electrical interfaces of fire control, navigation and missile, through POLARIS A3.

SPO organized, on 7 January 1957, a POLARIS/Submarine Special Steering Group — later known as



Special Projects Office Organization — 1957

the Steering Task Group (STG) — to advise an optimum missile and submarine envelope, and to assist in monitoring developments. It was formed from senior members of the government-industry team (including academic organizations) who were empowered to commit their parent organizations to a course of action without lengthy referral to high management. Reporting to the STG, which was chaired by the Technical Director, were several working-level committees, headed by the SP Technical Branch Heads. The STG management concept, like the basic organization, was a major factor in the fleet ballistic missile (FBM) success and has continued in existence, monitoring technical progress and formulating new concepts.

Lockheed was authorized by the SPO on 17 December 1956 to proceed with the development of the POLARIS with Aerojet developing the propulsion system. The missile was to have a 1500 nm range and be operational in 1965. In May 1957, the program was redefined by SSPO establishing: POLARIS A, a 1200 nm interim surface launch submarine capability by 1 January 1963 and POLARIS B, a 1500 nm submerged launch capability by 1 January 1965.

Intelligence sources indicated continuous advancements in Soviet missile and nuclear weapons capability. This, coupled with the launch of Sputnik I on 4 October 1957, spurred a series of additional POLARIS program accelerations:

22 October 1957 — The SECNAV proposed to the SECDEF:

1. A 1200 nm operational missile (POLARIS A) by December 1959.
2. Early operational FBM submarine by early 1962.
3. A 1500 nm missile (POLARIS B) by mid-1963.

28 October 1957 — SPO began planning for:

1. An interim 1200 nm missile by early 1961.
2. The 1500 nm missile operational by June 1963.

26 November 1957 — SPO established the accelerated POLARIS A (now A1) program:

1. Tactical (A1) missile demonstrated by December 1960.
2. First submarine (SSBN) deployed in June 1961.
3. The 1500 nm missile operational by 30 June 1963.

4 April 1958 — SPO established an Emergency Program:

1. Deployment of a 1000 nm or greater development missile (A1X) by April 1960 for 3 SSBNs (April, July, and October).
2. If the emergency did not materialize, deployment of the 1200 nm A1 in 3 SSBNs, beginning October 1960.

22 November 1958 — SPO directed development of the 1500 nm "B" missile now referred to as POLARIS A2, to be deployed on the 6th SSBN in October 1961.

5 February 1959 — SPO further modified the program:

1. POLARIS A1 deployed in October 1960 in the first of 3 SSBNs.
2. POLARIS A2 to be operational in April 1962.
3. With an objective of having a 2500 nm missile — "C".
4. An emergency capability to deploy one SSBN by 30 April 1960 with A1-type missiles (either development or production type missiles).

Meanwhile, many parallel activities were underway. Missile subsystems development were combined into various test programs, both on the ground and in-flight test programs which would demonstrate performance in actual operational flight environments.

In January 1957, Lockheed launched the first in a series of 22 Flight Test Vehicles (FTV). The initial series of tests investigated thrust reversal (using blow-out ports on the rocket motor's forward dome) at low altitude and then, using a two-stage vehicle, demonstrated effectiveness at high altitude. An existing single nozzle motor was modified to carry a plenum chamber and four nozzles to simulate the proposed POLARIS geometry. It carried jetevators (metal quadrant activated into the rocket motor nozzles) and demonstrated thrust vector control (TVC) of the aerodynamically-unstable missile.

Lockheed had been conducting atmospheric reentry body (RB) tests for the Air Force for some time using the solid-propellant, three-stage X-17 test vehicle. The Navy benefited from this activity and redesignated the X-17 as the FTV-3 for continuing POLARIS reentry experiments. The vehicle was a three-stage reentry vehicle wherein two stages were ignited in sequence during the ascending part of the trajectory. The last stage was ignited on descent and an RB was driven into the atmosphere at a very high Mach number, thus testing reentry nose cones and the ability of materials to withstand the reentry environments.

In the area of solid-propellant rocket motors, Aerojet, by mid-1957, had conducted large-scale boost propulsion tests with increases in specific impulse, confirming the prior experiments conducted by Atlantic Research Corporation. The gains in impulse and reduction in inert weights support the POLARIS performance objectives and missile size goals.

Development of the missile guidance system was conducted by the MIT Instrumentation Laboratory under Dr. Charles Stark Draper. The resulting system was approximately six times smaller than the JUPITER system.

Actual flight testing of POLARIS (AXs) began on 24 September 1958 at Cape Canaveral and ended on 2 October 1959. Initially, POLARIS prototype AXs were flown. There were 17 of these of which 5 were successes; 11 partial successes and one failure. The series of tests were followed by 40 A1X flights which were more representative of the desired tactical missile. These flights began on 21 September 1959 and completed on 17 November 1960, two days after the USS George Washington deployed. This test series had 28 successes, 11 partials and one failure.

NOTE: The innumerable technical challenges and problems which were resolved during the development phase of POLARIS A1 are not repeated here. They are highlighted in various other documents including references (1), (2) and (15).

The first submerged submarine-launched functional POLARIS missile occurred on 20 July 1960 at Cape Canaveral when the USS George Washington (SSBN-598) fired the A1X-31 on a successful full-range demonstration. A second missile was successfully launched 2 hours and 53 minutes later.

Various Weapon System Interface tests were conducted:

Peashooter. At Hunter's Point Naval Shipyard, San Francisco, California, a launching of full-scale static test inert POLARIS vehicles from a Westinghouse Launch tube into the waters of San Francisco Bay. In later tests, the vehicle was "caught" before it fell into the Bay by "sky catch," a crane-type arrangement.

Popup. An underwater launch tube assembly off San Clemente Island, California, launching of full-scale inert vehicles. Here again, there was a test vehicle "catching" arrangement, but called "Fishhook." There was also launching of test vehicles with a cut-grain (short burn time) propellant, FS motors to test underwater launch, first ignition and initial FS stability.

SIRALOP. (POLARIS spelled backwards) — Vertical acceleration test equipment where missile components were "shot" along a vertical track to simulate initial SSBN launch conditions and function capability. It is interesting to note that Missile Systems Division (MSD) requested contractual coverage for this test setup but SP 27 was not convinced it was needed. SP 27 in turn wanted dual-channel ignition designed into the missiles ignition interlocks and MSD was not convinced it was necessary. At a Missile Coordination Committee Meeting (MCCM) at Lockheed in 1958, "horse trading" was done; SP — "you give me dual channels and I'll provide SIRALOP." MSD "agreed." Thus, decisions were made and the program moved on.

Ship Motion Simulator (SMS). At Cape Canaveral Test Range, Florida, Westinghouse launching system with a hydraulic "heaving" system attached in order to simulate ship's motion was dug into the ground (sand) at the Cape with a "sandbox" next to it to catch the inert test vehicle after ejection. It was used to conduct demonstration of missile behavior during a surface launch.

USS Observation Island (EAG-154). A mothballed Mariner ship was activated and a complete SSBN Weapon System installed for the purpose of launching "live" test vehicles. The AX-22 was the first ship-launched vehicle from the Observation Island on 27 August 1959. This was followed by a complete weapon system test with the launching of A1X-18 vehicle on 29 March 1960. SSBN-type navigation, fire control, and launching equipment were used.

LUMF. LMSC Underwater Missile Facility, Sunnyvale, California. Underwater vehicle travel and transition through the ocean's surface tests were conducted on scale missile models, under modeled environments (e.g., sea, swell, atmosphere pressure).

The USS Proteus (AS-19), a submarine tender in mothballs at the Naval Shipyard, Charleston, South Carolina, was activated and converted into the first POLARIS FBM submarine tender, commissioned on 8 July 1960.

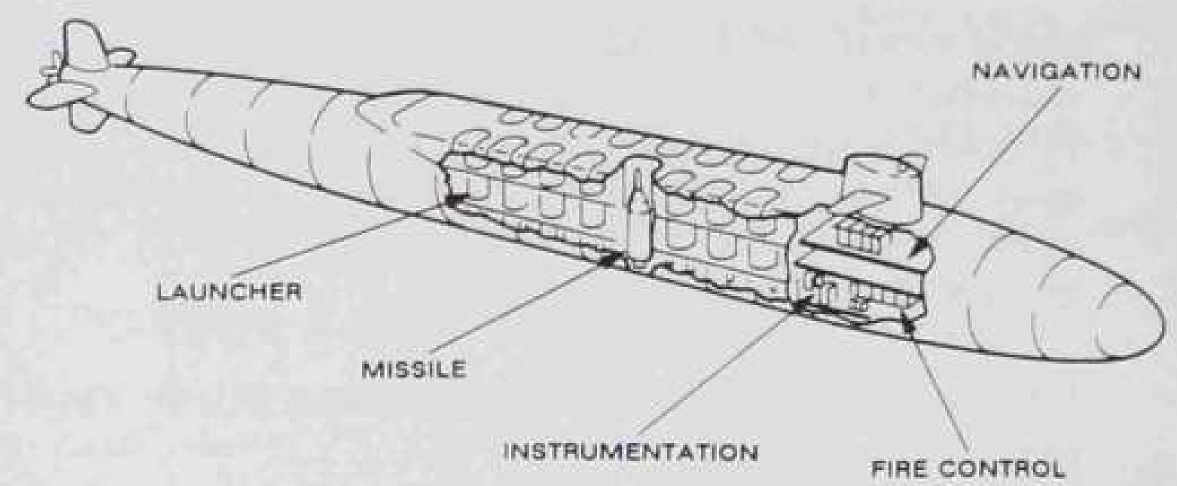
In September of 1958, construction of POLARIS Missile Facility, Atlantic (POMFLANT) at Charleston, South Carolina, was approved, and it was commissioned on 29 March 1960. This facility assembled, checked out, and loaded missiles on the SSBN for operational patrol.

The Submarine Story. The idea which developed into the present FBM Strategic Weapon System (SWS) was derived from a World War II German invention described in some captured Nazi documents taken during the latter part of the war from a captured, high-level German headquarters. The proposal involved the installation of mortar tubes on the deck of a U-boat and the firing of the mortars while the tubes were still partly submerged.

Based on this general concept, the Navy proposed to develop a fleet of submarines with missile-launching capabilities. The Navy initiated the design of a POLARIS-type submarine (SSBN). However, the time requirements of the accelerated programs demanded an interim submarine.

With some compromise in delivery schedules, the Navy agreed in January 1958 to slip the launch dates for two hunter-killer skipjack types of fast attack submarines in order to convert two hulls to missile-carrying FBM Weapon System ships. These first two are essentially of the hunter-killer type with a missile compartment inserted between the ship's control-navigation areas and the nuclear reactor compartment. The keel of the first of these two ships had already been laid at Electric Boat, Groton, Connecticut, as the "Scorpion" and it was actually cut apart in order to insert the new 130 ft missile compartment ("Sherwood Forest"), thus extending the ship's length. At other shipyards, three more ships of the same type were built, making a total of five. The shipyards were Newport News Shipbuilding and Drydock Company, Mare Island Naval Shipyard, and Portsmouth Naval Shipyard. These were designated the 598 class ships since the first submarine, the USS George Washington was the SSBN-598. The term SSBN means Ship Submersible Ballistic (Nuclear) with the "Nuclear" referring to the ship's propulsive power.

The President signed the FY 58 Supplemental Appropriation Act on 12 February 1958 funding the first three submarines. The construction, which had begun in January 1958, used funds "borrowed" from other Navy programs.



POLARIS Submarine

On 1 July 1958, Submarine Squadron Fourteen was established.

The President authorized construction of submarines 4 and 5 on 29 July 1958.

Construction of SSBN 6 was authorized by the President on 23 December 1958.

It should be noted that SPO on 28 November 1958 directed initiation of the second-generation missile, POLARIS A2 (1500 nm), to be loaded on the sixth SSBN in October 1961.

On 27 June 1959, the President authorized construction of SSBNs 7, 8, and 9.

On 1 July 1959, the FBM Program had, as its objective, a complete POLARIS/SSBN system with a 1200 nm range in 1960. Nine submarines and a submarine tender were authorized.

By 1 July 1960, a second submarine tender had been authorized by the President.

On 15 July 1960, the President authorized construction of SSBNs 10, 11, 12, 13, and 14.

Not to get ahead of the chronology of missile development, but continuing with the submarines and tenders, the third SSBN tender was authorized by President John F. Kennedy on 29 January 1961, along with SSBNs 15, 16, 17, 18, and 19.

On 19 July 1961, the President authorized construction of SSBNs 20 through 29.

The President signed the FY 63 Appropriations Act on 10 August 1962, providing funds for SSBN 30 through 35 and long-lead items 36 through 41, plus funds for a fourth submarine tender.

41 SSBNs were authorized by 2 July 1964, with the entire force to be operational in 1967.

On 15 November 1960, the USS George Washington (SSBN-598) deployed on operational patrol with 16 POLARIS A1 (1200 nm) missiles 4 years 11 months after RADM William F. "Red" Raborn became the director of SP, and 3 years 11 months after the SECDEF authorized the POLARIS

"Unto 'US' a Star Was Born" — POLARIS.

HIGHLIGHTS (1955 - 1960)

The following highlights were extracted from what is believed to be the first history of POLARIS — "POLARIS Development Highlights 1956 to 1964 by M. E. Murphy, RADM (ret), Senior Staff Engineer, LMSD dated 1964 (reference 1):

11 Jul 1955	LMSD was requested by CNO letter (serial 00932) to comment on a submarine-launched, long-range, ballistic missile, currently under consideration by the Navy.
5 Aug 1955	Lockheed published "Proposal for the development of an FBM (MSD/1230), showing that the company had experience in carrying out optimization analyses in connection with missile systems.
9 Sep 1955	The SECDEF defined the responsibilities in the development of an IRBM program, established a JANBMC to provide early IRBM shipboard capability, and proposed that the liquid-propelled JUPITER be adapted to meet Navy needs.
19 Sep 1955	Lockheed published "Submarine Ballistic Missile — Two-Stage Propellant" (MSD/1362), to investigate the feasibility of such a missile capable of delivering a 3000 lb warhead a distance of 1000 nm.
1 Nov 1955	Lockheed responded to CNO's letter of 11 July 1955, with transmittal of "A Preliminary Study — Fleet Ballistic Missile" (MSD/1399).
17 Nov 1955	SECNAV directive, serial 00301P51, defined the Navy's role in the JANBMC, designated the Bureau of Ordnance as the primary bureau in the program, and established a flag rank Project Office billet in Buord, reporting directly to the SECNAV for heading up the program; a billet shortly to be filled by RADM William F. "Red" Raborn.
28 Nov 1955	The Navy announced its long-range objective to develop solid-propellant motors for ship-launched ballistic missiles, which could be substituted for liquid motors (JUPITER) and thus alleviate the serious hazards, difficult design, and logistics problems associated with the JUPITER.
5 Dec 1955	RADM William F. "Red" Raborn assumed duty as Director, SPO.
13 Dec 1955	Messrs. Robert Gross, Hall Hibbard, and Willis Hawkins represented Lockheed in a meeting with Buord and presented a plan (MSD/1467) for fulfilling the responsibilities of an FBM Weapon System contractor, in terms of tasks as outlined by Buord.
19 Dec 1955	The CNO established the Operational Requirements for an FBM, in serial 00303P37, which called for the development of a 1500 nm IRBM, using JUPITER, with an initial surface ship capability, to be followed downstream by a submarine-launched version.
29 Feb 1956	Lockheed published "Solid Fuel FBM System, Phase I — Proposal ML-296," in response to a request from the Navy, outlining a study contract which would analyze the feasibility of using solid propellants for a submarine-launched FBM of 1500 nm range.
Mar 1956	The JANBMC authorized a navigation development ship called Mariner I, a weapon system test and development ship called Mariner II, an FBM combatant ship development program, and an FBM submarine development program.
20 Mar 1956	The JANBMC approved the Navy's parallel solid propellant program. With this authority, SPO entered into contractual discussions with Lockheed and Aerojet in furtherance of the program.
11 Apr 1956	By Letter of Intent (NOrd 17017) Lockheed was assigned the task of investigating the possibility of using solid-propellant motors for FBM weapon system application, the surface ship version to be available for operational evaluation 1 January 1960; submarine version specified for operational evaluation 1 January 1965.

10 May 1956 — Lockheed reported, in MSD/1691, its evaluation of a proposed concept of a solid-propulsion test vehicle, consisting of a clustered six-motor FS, surrounding a single motor SS. This concept (the short-lived "6 plus 1") was considered technically feasible but exceedingly heavy (heavier than JUPITER).

Summer 1956 — A series of dramatic scientific breakthroughs gave impetus to the FBM program: (1) Aerojet demonstrated the feasibility of developing large solid-propellant motors for long-range missiles, (2) MIT proposed inertial guidance systems weights considerably less than existing systems, and (3) the AEC achieved a warhead breakthrough having a yield in total weight extremely attractive for IRBMs.

Sep 1956 — All these results were so encouraging that RADM Raborn decided to move along with a smaller-sized missile which he named "POLARIS." He appointed an STG to study such a program. On 27 September, he presented the POLARIS program to CNO. POLARIS, as the name of the proposed Navy ship-launched missile, thus originated officially in September 1956.

8 Oct 1956 — At the request of SP, LMSD transmitted "A Design Study on POLARIS Ballistic Missile (Revised)" (MSD/2500-1).

Oct 1956 — LMSD strongly recommended to the Navy that underwater launching of POLARIS be considered immediately, rather than in the distant future; also that tube ejection be adopted.

8 Dec 1956 — The SECDEF authorized the Navy to terminate participation in the JUPITER program and to proceed with the development of an optimum IRBM capability at high priority.

15 Dec 1956 — LMSD published "The POLARIS Weapon System" (MSD/2503).

17 Dec 1956 — By SPO Technical Directive 3-56, Lockheed was authorized to proceed with the development of the POLARIS missile, with Aerojet developing the propulsion system.

19 Dec 1956 — The SECNAV announced the reorientation of the FBM program from the liquid-fueled JUPITER to a solid-propellant IRBM system. The SECNAV also established a Navy BMC.

Jan 1957 — Lockheed published "POLARIS Master Development Plan," and an STG was convened in Washington on 7 January 1957 for the purpose of defining the POLARIS-Submarine Envelope by March 1957. The recommendations of the STG, including the basic design characteristics of the POLARIS missile, established the guidelines for subsequent development work. Overall parameters included numbers of submarine launch tubes (16), diameter of missile (54 in.), length of missile (28.5 ft), weight of missile (approximately 14 tons), and launch tube dimensions, including excess length (approximately 3 ft) in the lower part of the tube to accommodate, at some future date, longer missiles than the one initially planned. Lockheed representation on the STG and its working committees included: W. M. Hawkins, S. W. Burriss, F. J. Bednarz, L. N. Ridenaur, F. Hoyt, S. H. Browne, and W. A. Fiedler.

11 Jan 1957 — Started flight testing of flight test vehicles to examine special features to be used in POLARIS. First were the Phase V vehicles, for low altitude testing of thrust termination. Phase VI and the FTV-1, FTV-3, and FTV-4 series were to follow during the year.

3 Apr 1957 — The final report of the STG, "Recommendations for POLARIS-Submarine Envelope," was published.

Apr 1957 — A series of underwater launch ejection method were assigned by SP to LMSD for evaluation: (1) gas cavity enclosing whole missile, (2) wet (bare) missile, (3) bubble enclosing missile, (4) foam enclosing missile, and (5) gas bladder erected on launch tube enclosing missile. (NOTE: Lockheed strongly endorsed the wet (bare) missile method and won out over considerable opposition.)

8 May 1957 — "FBM Technical Development Plan," issued by SP, provided further program definition, including delivery of one interim submarine FBM Weapon System to the Operational Development Force on 1 January 1963.

May 1957 — Design started on Polaris Pre-Prototype A (later designated AX), length 28.5 ft, diameter 54 in., weight 29,000 lb.

Jul 1957 — STV-1A tests started at Peashooter launching facility at Hunter's Point.

4 Oct 1957 — Russian launching of Sputnik I precipitated pressure on U.S. space effort and POLARIS program.

28 Oct 1957 — SPL Technical Instruction 63-57 directed study and planning to be undertaken immediately to determine overall requirements for an accelerated and augmented POLARIS program, with an interim 1200 nm missile to be ready in early 1961 (a 2-year acceleration), and the 1500 nm missile to be operational by June 1963 (an 18-month acceleration).

26 Nov 1957 — SPL Technical Instruction 77-57 established the A1 program and spelled out requirements for first flight test in June 1959, A1P missile to be demonstrated by December 1960, first SSBN to be deployed in June 1961, full operational capability by 30 June 1963 with next-generation missile.

31 Dec 1957 — The first POLARIS "A" motor was fired successfully using ANP-2639 propellant (no jetevators).

Dec 1957 — The LUMF was placed in operation at Sunnyvale.

15 Jan 1958 — "POLARIS Missile System Development Plan" was published by LMSD, specifying an A1 Emergency Capability of deploying submarines in October 1960 and in February and June 1961, with missiles diverted from the A1X flight test program.

23 Mar 1958 — The first launching (STV-1B) from the Operation Popup installation at San Clemente Island, California, demonstrating the underwater launch method using a bare missile.

4 Apr 1958 — SPO letter, serial 00217 (Lockheed/114338), accelerated the program further, calling for (1) an emergency A1 capability for 3 SSBNs in April, July, and October 1960 (1100 nm range); (2) and an interim operational capability with A1P missiles for 3 SSBNs in October 1960. This represented a 3-year acceleration over original dates. This was designated the Mk IV Mod 4 program, the final version of which was published on 28 September 1958.

21 Jun 1958 — The first dynamic interstage separation test was successfully conducted at AGC.

16 Aug 1958 — The first firing of the POLARIS Captive Test Facility at Santa Cruz Test Base (SCTB) was successfully accomplished using an XM-36 motor.

24 Sep 1958 — First POLARIS missile flight test (AX-1) at Cape Canaveral. It was a "partial success."

28 Nov 1958 — SPL in serial 009952-58 directed the initiation of a Mk V Development Program, based on a second-generation missile A2 (a 1500 nm missile), 30 in. longer than the A1, to be loaded on the sixth SSBN in October 1961.

5 Feb 1959 — SPL letter serial 01201-59 modified the Mk V Mod 1 program objectives to call for (1) an early A1P operational capability in October 1960 in 3 SSBNs; (2) an operational capability in April 1962 of the A2 missile; (3) an advanced operational capability of a new generation 2500 nm missile (then referred to as C-missile); and (4) an emergency capability to load and deploy one SSBN by 30 April 1960 with 16 A1-type missiles, to be diverted from the flight test program, if necessary. (This resulted in several A1XPs and A1FPs being fabricated and assembled in advance of the A1Ps.)

20 Apr 1959 First fully-successful AX missile (AX-6) was flight tested.

8 Jun 1959 The USS George Washington (SSBN-598) was launched at Groton, Connecticut.

27 Aug 1959 First launching of POLARIS pre-prototype AX vehicle (AX-22) from EAG-154. Successful flight.

4 Sep 1959 SP TWX 041535 September 1959 (LMSD/471197) established the groundrules for a Mk VIII Development Program with the POLARIS C missile being replaced with an A3 missile which was to be operationally available in 1965.

2 Oct 1959 Last AX missile (AX-20) was flight tested, bringing the 17-flight AX program to a conclusion. Total score for AX program was 5 successes, 11 partial successes and 1 failure.

30 Dec 1959 The USS George Washington (SSBN-598) was commissioned.

7 Jan 1960 First fully-guided flight (A1X-7). It was successful.

23 Mar 1960 The first Launch Test Vehicle (LTV) was successfully launched from SSBN-598.

29 Mar 1960 First EAG launch of A1X missile (A1X-18). Partial success.

14 Apr 1960 First Popup live motor launching (STV-2A-2) at San Clemente demonstrated the transition from underwater to (short) powered air flight.

18 May 1960 "POLARIS Missile System Program Plans and Requirements Survey, Mk IX Mod 4" was issued by LMSD. Among the program objectives was an A2A missile, 1500 nm range with a Mk II reentry system and Mk II guidance system, planned for operational availability in July 1964 (the reentry and guidance planned for A3).

13 Jun 1960 The first SSBN, USS George Washington (SSBN-598) was "ready for sea."

22 Jun 1960 First successful launch and flight of A1X missile (A1X-32) from EAG.

20 Jul 1960 The USS George Washington (SSBN-598) made history by launching two POLARIS missiles (A1XP-5 and A1XP-8) from a submerged position off Cape Canaveral. Both made successful flights.

15 Aug 1960 "POLARIS A3 Missile Development Plan" was published by LMSD as an initial planning document for A3, which was to replace the A2A. The A3 would have 2500 nm capability, Mk II RB and Mk II guidance, with initial shipfill in April 1965 (later changed to mid-1964).

31 Oct 1960 SPL Technical Directive 56-60 gave LMSD authority to proceed with the development of the A3 missile.

10 Nov 1960 The first A2X missile (A2X-1) was launched from Cape Canaveral. It was a successful flight, going 1414 nm.

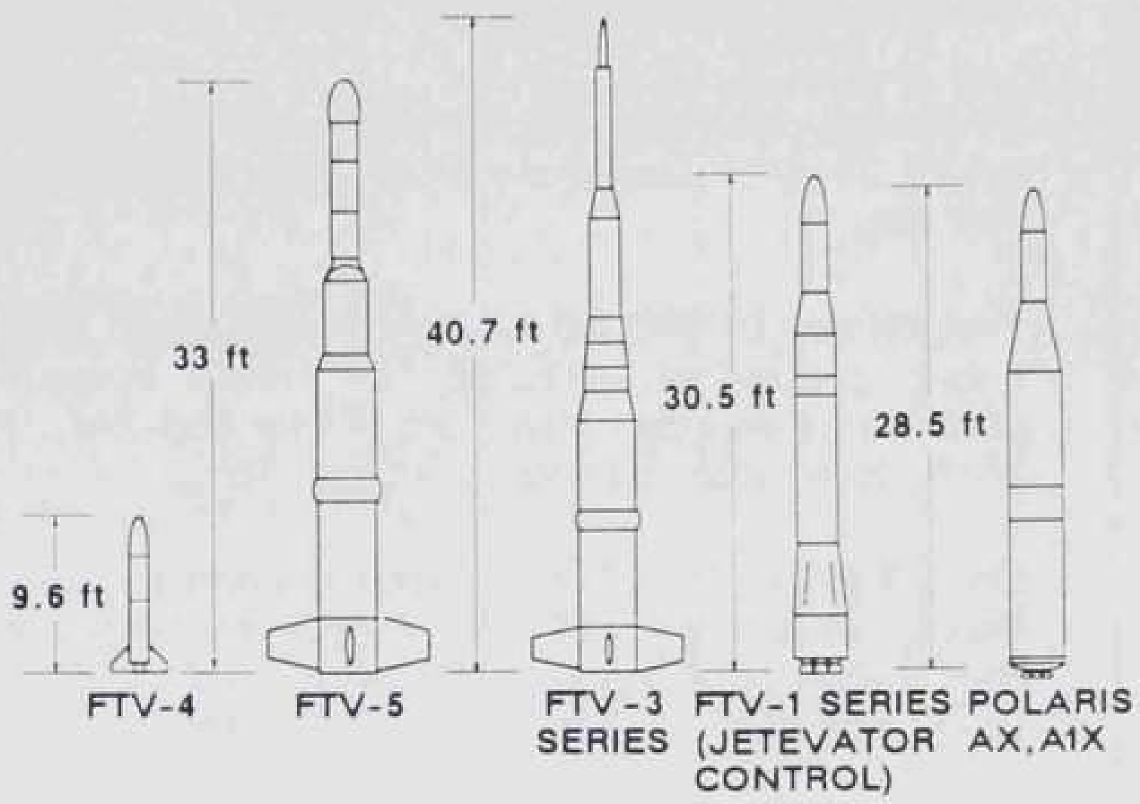
15 Nov 1960 The USS George Washington (SSBN-598) deployed (with 16 missiles).

17 Nov 1960 The 40th A1X flight (A1X-52) was made, marking the end of the A1X flight test program except for A1X-50 and A1X-51. These two missiles were set aside for future use and were configured for fluid injection TVC (for the A3X program) and were fired in the fall of 1961; A3X-50 on 29 September 1961 and A3X-51 on 5 December 1961. Both were successful making the overall score for 42 A1X flights as 30 successes, 11 partial successes, and 1 failure.

FLIGHT TEST SUMMARY AND MAJOR PROBLEMS

As mentioned earlier, this document will not attempt to outline the innumerable technical challenges which were overcome or the problems which were resolved. However, it is worthwhile to provide a brief review of the development flight test results and the resolution of their major problems.

The following flight test summary and major problems were excepted from the first history of POLARIS — "POLARIS Development Highlights 1956 — 1964", reference (1) by LMSD Senior Staff Engineer, M. E. Murphy, RADM (ret).



Flight Test Vehicles

FTV FLIGHT TEST SUMMARY

Inclusive Dates	Vehicles Testbed	Purpose and Description	Success	Failure
		Phase V Series		
1-11-57 - 3-2-57	5	To investigate low-altitude performance of small-scale, aft-mounted thrust termination device on 10 KS 2500 solid-propellant rocket motor; also to develop instrumentation and data analysis techniques for future tests.	5	0
		Phase VI		
4-10-57	1	To test propulsion and thrust reversal at high altitude on a 10 KS 2500 rocket motor boosted by an XM-20 rocket motor.	0	1
		FTV-1 Series		
8-1-57 - 6-24-58	9	Evaluation of thrust reversal 4-nozzle motor, single-stage XM 36 motor; also angle-of-attack sensing methods and temperature design data.	9	0
		FTV-3 Series		
7-17-57 - 10-1-57	4	Three-stage testing of reentry, nose cone, and surface roughness, and various RB materials, using X17 RB Test Vehicle adaptation.	4	0
		FTV-4 Series		
6-27-57 - 7-16-57	2	Low-altitude testing of propulsion and thrust reversal, using single stage 10 KS 2500 rocket motor.	2	0
		FTV-5 Series		
8-16-57	1	High altitude testing of propulsion and thrust termination (forward position thrust termination) on a 10 KS 2500 motor boosted by XM 20 motor.	1	0
		Total Flights — 22	21	1

AX FLIGHT TEST SUMMARY

AX General Characteristics

Two-stage, solid-propellant vehicle; weight 29,800 lb, length 28.5 ft; diameter 54 in.; range approximately 700 nm.

First stage (19,000 lb) — steel motor case; polyurethane propellant (15,200 lb) with ammonium perchlorate (oxidizer) and aluminum additives, ANP 2639; jetevators; interstage section (IS).

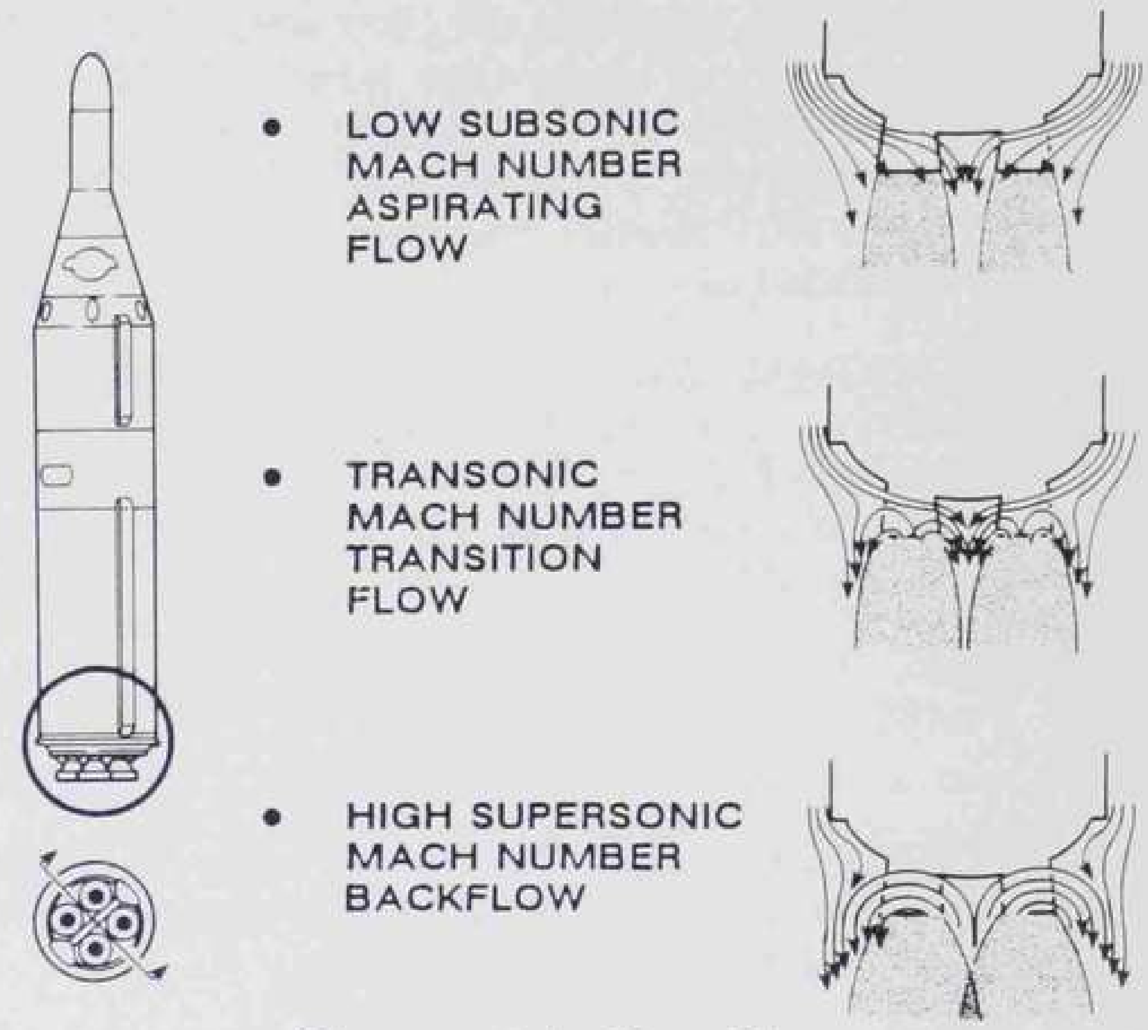
Second stage (10,000 lb) — steel motor case; polyurethane propellant (7,200 lb) with ammonium perchlorate (oxidizer) and aluminum additives, ANP 2673; jetevators; equipment section (ES).

AX Major Development Problems

The outstanding development problem in the preflight stage was **sticking jetevators** on the FS motor. (On the SS, this sticking was minimal.) This problem plagued static motor tests and caused the flight program to slip a couple of months while waiting a solution. The cause of the sticking was aluminum oxide deposits. It was remedied by removing the jetevator seals and making room for the deposits to build up without interfering with jetevator movement. While virtually eliminating jetevator sticking, the seal removal did allow more flame "blow back," which contributed somewhat to an aft end heating condition which became a serious problem in flight test.

AX-1, fired on 24 September 1958, did not pitch over due to a programmer failure, and instead went straight up in the air until cut down at 27 sec by command destruct. The next flight, AX-2, had a different problem. It experienced an explosive bolt failure in the Marmon Clamp which released the nonpropulsive head cap. The FS chuffed on the pad at both ends. The SS ignited and took off but was destructed at 7 sec, landing in the vicinity. The explosive bolt failed in tension, initiating the firing of the charge mechanically. This casualty caused extensive investigation and delayed the next flight. Corrective action was to modify the clamp and use a larger explosive bolt (3/4 in. instead of 5/8 in.).

The outstanding AX flight problem came with AX-3 and later received the name of "Hot Foot." As soon as AX-3 reached supersonic speed, at approximately 24 sec, aft end temperatures started to rise (as later determined). At 28 sec, control was lost due to a servo valve short, and the vehicle had to be destructed (at 82 sec). At that time, the cause of the aft end heating was not well understood. However, when AX-4 lost control at 45 sec, due to a jetevator feedback loop failure and had to be destructed (at 113 sec), the cause could be seen more clearly. This led to the conclusion (later fully substantiated) that an aerodynamic "reverse flow" was taking place at supersonic speeds which had the effect of turning back toward the base of the motor, the flame/hot gases, resulting in excessive heating.



Characteristic Heat Flows

This "reversed flow" with its attendant heating was researched and tested at great length in "Operation Hot Foot," which included sled and wind tunnel tests. Even before the tests could be set up, the antidote to aft end heating was evolved and became known as "Operation Phoenix." It consisted of putting fiberglass flame shielding, supplemented with silicone rubber, over hydraulic packages, cabling, and motor dome, in order to form a barrier to flame and hot gases. The first attempt, on AX-5, was in part successful, but there were jetevator sticking and progressive nozzle deterioration, to which aft end heating may have contributed. By AX-6, the Phoenix protection became fully effective, resulting in a successful flight.

A variety of other problems, none outstanding like "Hot Foot," occurred in the AX flight program. There were seven flight failures in the propulsion area: explosive bolt (AX-1), lost jetevator (AX-11), excessive SS chamber pressure (AX-15), aft end closure (AX-20), SS head end (AX-10 and 18), and jetevator sticking and nozzle deterioration (AX-5). In the aggregate, propulsion was a major problem and extensive corrective measures were in progress throughout the program, too detailed for a "highlights" type of account.

AX FLIGHT TEST SUMMARY

Missile Number	Date/ Site	Resume of Results	Success	Partial Success	Failure
1	9-24-58 FP	Programmer failure, no pitch over, went straight up, destruct 27 sec, landed Banana River and vicinity.		X	
2	10-15-58	Explosive bolt failure, releasing non-propulsion head cap, FS motor chuffed on pad, SS ignited and took off, destructed 7 sec, landed in vicinity.			X
3	12-20-58 FP	Lost control 28 sec, servo unexpected servo valve short due to aerodynamic aft end heading at supersonic speed (to be known as "Hot Foot"), destructed 82 sec.		X	
4	1-19-59 FP	Lost control 45 sec, jetevator feedback loop failure ("Hot Foot"), separated, destructed 113 sec.		X	
5	2-27-59 FP	OK for 19 sec, then No. 4 jetevator started sticking, gradual loss of No. 4 nozzle, lost control 37 sec (aft end had heat protection added known as "Phoenix").		X	
6	4-20-59 FP	Successful flight thrust termination 19 sec early due to an unincorporated EO (Phoenix heat protection was effective).	X		
8	5-8-59 FP	Successful flight 705 nm.	X		
7	5-18-59 FP	Lost control at first separation, intermittent short in control system (yaw).		X	
10	6-12-59 FP	OK through first separation, terminated 1.1 sec after separation, head and motor case failure SS. (Other system anomalies were also suspected, but later proved groundless.)		X	
9	6-29-59	Successful flight, 704 nm,	X		
11	7-15-59 FP	Lost jetevator on launch. OK to 31 sec, made outside loop, separated and SS recovered, destruct, 73 sec.		X	
15	8-6-59 FP	OK through first separation, terminated 3 sec after separation, SS chamber pressure excessive, thrust termination port 5 blew, auto destruct.		X	
13	8-14-59 SMS	Successful flight 690 nm. First SMS firing.	X		
18	8-25-59 FP	SS motor blew (head end) shortly after first separation (similar to A3X-10).		X	
22	8-27-59 EAG	Successful flight 711 nm. However, no thrust termination and second separation.	X		
14	9-27-59 FP	Aborted, pitch up at 39 sec, No. 3 flame baffle and feedback wires burn out, high JV immersion, destructed 47 sec. TRACE instrumentation to investigate system anomalies suspected on A3X-10 and 18.		X	
20	10-2-59 FP	OK for 25 sec, FS aft end blew out 35 sec, auto destruct SS.		X	
		Total AX Flights — 17	5	11	1

A1X FLIGHT TEST SUMMARY

A1X General Characteristics

Dimensionally similar to AX; weight 28,800 lb, length 28.5 ft; diameter 54 in.; range approximately 1000 nm (with instrumentation).

First stage (18,400 lb) — steel motor case; polyurethane propellant (15,200 lb) with ammonium perchlorate (oxidizer) and aluminum additives, ANP 2639 (same as AX); jetevators; IS.

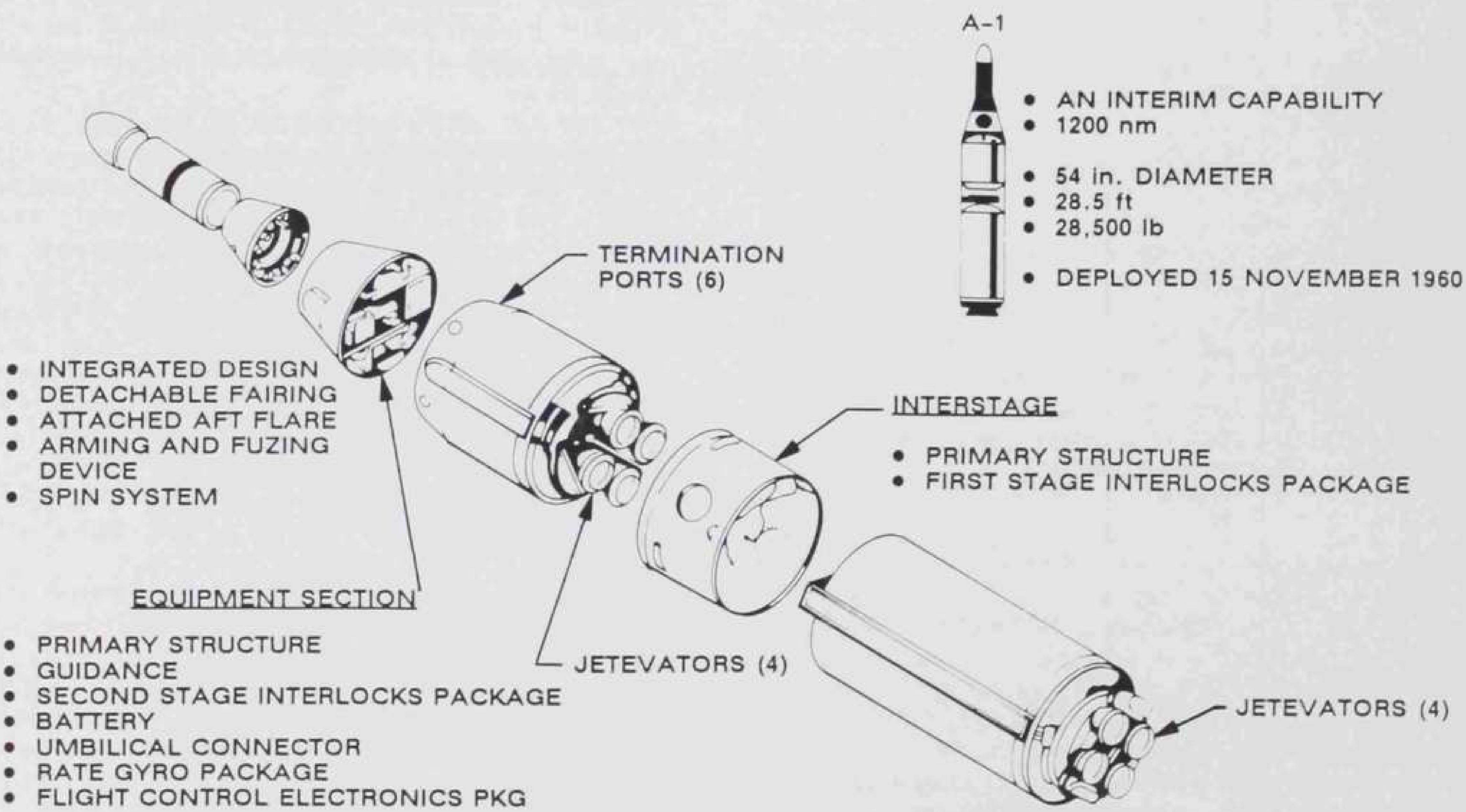
Second stage (9,400 lb) — steel motor case; polyurethane propellant (7,300 lb) with ammonium perchlorate (oxidizer) and aluminum additives, ANP 2655; jetevators; ES.

NOTE: Two additional A1Xs, A1X-50 and A1X-51, were specially configured with SS fluid injection TVC (for A3X development) and were flown successfully on 9-29-61 (A1X-50) and 12-5-61 (A1X-51). These are recorded under "Pre-A3X Flight Test Summary." Lumping A1X-50 and A1X-51 with the 40 previous A1X flights, the overall score is 30 successes, 11 partial successes, and 1 failure.

A1 Major Development Problems

The first major development problem in the A1X flight test program manifested itself in A1X-2, the SS of which failed in the vicinity of No. 5 thrust termination port, due to overheating. It was an insulation and bonding problem, and was a continuation of the type of trouble experienced in AX-10, AX-15, and AX-18. These also failed in the head end. A1X-2 generated an extensive investigation of head end insulation and bonding, which resulted in "fixes" starting with A1X-3. Also, A1X-3 received special head end instrumentation termed "Hot Head." The fixes included a continuous boot and potting with Mk 203 compound. This seemed to do the job, as A1X-3 and A1X-4 made successful flights — thereafter, included six good ones.

The head end fix with a continuous boot and potting solved one problem but introduced another. A1X-14, A1X-15, and A1X-16 experienced thrust termination port failures; they did not open up and arrest the forward movement of the SS. On second separation, the SS, therefore, continued on and bumped the RB. The continuous boot was probably a major contributor to the anomaly. The solution to the new problem included scoring the boot around the periphery of each thrust termination port, replacing the Mk 203 potting with a Buna N rubber plug and other minor changes. The introduction of



POLARIS A1

these changes virtually eliminated thrust termination failures.

Other failures in the A1X flight program were of a random type, including two guidance malfunctions.

It was in the submarine Systems Development and Analysis Program (SDAP) firings that the most serious A1 problems developed. Some of these problems were associated with the underwater launch environment. Stowage launch adapters, the ignition system, and jetevators proved somewhat vulnerable.

In the early SDAP firings, stowage launch adapters misbehaved in this environment. After considerable attention, redesign, and Popup testing at San Clemente Island, California, the deficiencies were overcome.

There were also ignition anomalies and three lost jetevators in the SDAP program, reminiscent of the jetevator failure of AX-11. Project Alpha was set up at Popup to investigate the problem, starting on 7 April 1961. Popup conducted 22 launches, 14 of them with milligrain (cut grain) motors, in an effort to learn more about aft end hardware in the underwater launch environment. Project Alpha was unable to duplicate any SDAP failures, but a lot of information was acquired on cracked jetevator inserts and housings, which led to useful design changes, (e.g., steel housings). It was also found practicable and beneficial to fire without FS nozzle plugs (which were suspected of hitting and cracking some of the jetevators). Project Alpha represented a lot of effort, but it had many useful results.

In the spring of 1961, another problem came to light in the A1 SDAP program. It concerned SS nozzles. Some of them were deteriorating and failing late in SS flight. These nozzles of course undergo at altitude severe heating which is not present at sea level. Why they began to fail in production missiles, whereas they held together in the A1X flight tests, is still not clear. One school of thought held that the research and development (R&D) nozzles had greater tolerances and "slop" than the production type and the parts had room to expand under added heat; by the same token, the production nozzles, being made to print more rigorously, had closer tolerances and could not absorb the expansion.

At any rate, there existed a serious problem, whatever the cause. "Project FIXTO" was set up to analyze the problem and determine a fix. The mode of failure of the nozzle was judged to be slippage or loss of the exit ring, followed by loss or slippage of the astrolite liner and sometimes by cracking of the moly throat insert, resulting in nozzle "burn-through."

The solution arrived at entailed a two-fold change:

a. Insulate with a rubber boot the outer titanium shell of the nozzle to protect it from the additional heat encountered at altitude.

b. Install a retaining ring (moly band) around the threaded joint between the titanium shell and the moly exit ring. This was to prevent the nozzle from "belling out" under the influence of heat and allowing the exit ring to slip aft.

"Project TESTO" was established to evaluate and promulgate the above nozzle changes. Their validity was proven by special tests, including altitude chamber tests, which led promptly to the incorporation of the boot and retaining ring in SDAP missiles. They were fired successfully in August 1961.

These changes had the virtue of being effective but also were capable of being applied to an A1P missile in the launch tube. Installation was not easy, but it was worth the extra effort since it greatly reduced the number of failures of this type in fleet submarines.

"Project FIXTO" was the last major development problem in the A1 program, thus bringing to an end important design changes which had extended well into the A1 production phase.

A1X FLIGHT TEST SUMMARY

Missile Number	Date/ Site	Resume of Results	Success	Partial Success	Failure
1	9-21-59 FP	Successful flight 943 nm, no thrust termination but RB separated. TRACE instrumentation to detect malfunction related to AX-10/18. SS failures showed no misbehavior of suspected systems.	X		
2	10-12-59 FP	SS malfunctioned 6.4 sec after ignition in area of No. 5 thrust termination port, exhaust leakage to ES, premature separation (RB objective aborted). This flight initiated special investigation of SS head end insulation and bonding. Head end fixes started with A1X-3.		X	
3	11-20-59 FP	Successful flight 916 nm (had special SS head instrumentation termed "Hothead" which showed warm spot in vicinity of No. 5 thrust termination port).	X		
4	12-7-59 FP	Successful flight, 900+ nm.	X		
6	12-15-59 FP	SS motor failure near ignitor boss, gas to ES, ES disintegration 10 sec after SS ignition (probably O-ring failure initially).		X	
5	12-21-59 FP	No. 1 jetevator malfunctions 2 sec before first separation, hard left yaw, destructed 77 sec. SMS. Partial guidance.		X	
7	1-7-60 FP	Successful flight 902 nm. First fully-guided flight.	X		
8	1-13-60 FP	Successful flight 936 nm.	X		
9	1-20-60 FP	Successful flight 850 nm.	X		
10	1-27-60 FP	Successful flight 900 nm.	X		
12	2-4-60 FP	Successful flight 900 nm.	X		
11	2-10-60 FP	Successful flight 908 nm.	X		
13	2-20-60 FP	Electrical malfunctions at 71, 82, and 91 sec, destructed 105 sec.		X	
14	3-9-60 FP	Successful flight 982 nm. Thrust termination failure, SS bumped RB. Corrective program started.	X		
15	3-18-60 SMS	Successful flight 988 nm. Thrust termination failure. SS bumped RB.	X		
16	3-25-60 SMS	Successful flight 943 nm. Guidance and thrust termination malfunction; another SS-RB collision.	X		

A1X FLIGHT TEST SUMMARY (Continued)

Missile Number	Date/ Site	Resume of Results	Success	Partial Success	Failure
18	3-29-60 EAG	No. 2 port opened prematurely at 111 sec, leak to ES, did not separate 790 nm. First EAG launch. Random type failure.		X	
19	4-18-60 EAG	Malfunction to 800 cycle power during first separation. RB separation 59 sec.		X	
22	4-25-60 FP	Successful flight 1039 nm warhead development.		X	
23	4-29-60 FP	Successful flight 993 nm warhead development.		X	
25	4-29-60 FP	Successful flight 1004 nm warhead development.		X	
30	5-18-60 SMS	Successful flight 958 nm.		X	
17	5-23-60 EAG	Guidance malfunction prevented safe-to-arm signal (STAS), end of power flight, and thrust termination second separation. 1021 nm. 45 nm long.			X
27	6-7-60 FP	Malfunctioning safe arm unit, SS motor failed to ignite. First lightweight SS motor.			X
32	6-22-60	Successful flight 935 nm.	X		
34	6-23-60 SMS	Successful flight 960 nm.	X		
40	7-6-60 FP	SS motor explosion at 91 sec. Lightweight SS motor.		X	
39	7-7-60 EAG	FS motor aft closure lost at ignition, destructed 10.2 sec (Chinese fireworks!).			X
42	7-15-60 SMS	Successful flight 958 nm.	X		
41	7-19-60 FP	Successful flight 1031 nm.	X		
37	8-2-60 SMS	Guidance malfunctioned, landed 200+ nm to right, 956 nm.		X	
44	8-4-60 FP	Successful 1100 nm. Lightweight SS motor (first success). No SS flame shielding; demonstrated we did not need.	X		

A1X FLIGHT TEST SUMMARY (Continued)

Missile Number	Date/ Site	Resume of Results	Success	Partial Success	Failure
47	8-12-60 FP	Successful flight 959 nm. No SS flame-shielding.	X		
43	8-18-60 FP	Successful flight 1047 nm. No SS flame-shielding; no longer needed.	X		
45	9-2-60 FP	Successful flight 1064 nm.	X		
48	9-23-60 FP	Successful flight 664 nm (first medium-range shot).	X		
49	10-5-60 FP	Successful flight 1093 nm.	X		
53	10-10-60 FP	Successful flight 665 nm (medium-range shot). Last A1 warhead development flight.	X		
46	11-7-60 FP	Successful flight 960 nm.	X		
52	11-17-60 FP	SS motor failed 63 sec. Lightweight motor.			
		Total A1X Flights — 40	28	11	1

THE EARLY YEARS (1961 - 1964)

The USS George Washington (SSBN-598) slipped underwater on the first strategic FBM patrol on 15 November 1960. The USS Patrick Henry (SSBN-599) departed for patrol on 31 January 1961. The USS George Washington (SSBN-598) returned from patrol on 21 January 1961, coming alongside the tender USS Proteus (AS-19) at New London, Connecticut.

The USS Patrick Henry (SSBN-599) returned from patrol on 8 March 1961, but she came alongside the same USS Proteus which had moved to Holy Loch, Scotland becoming the first SSBN to use Holy Loch as a refit and upkeep anchorage.

The "Star" may have been born but the Navy's objective was to complete the development of the 1500 nm POLARIS A2, and have it operational in April 1962 plus a program gotten underway for a 2500 nm POLARIS A3 operational in 1965.

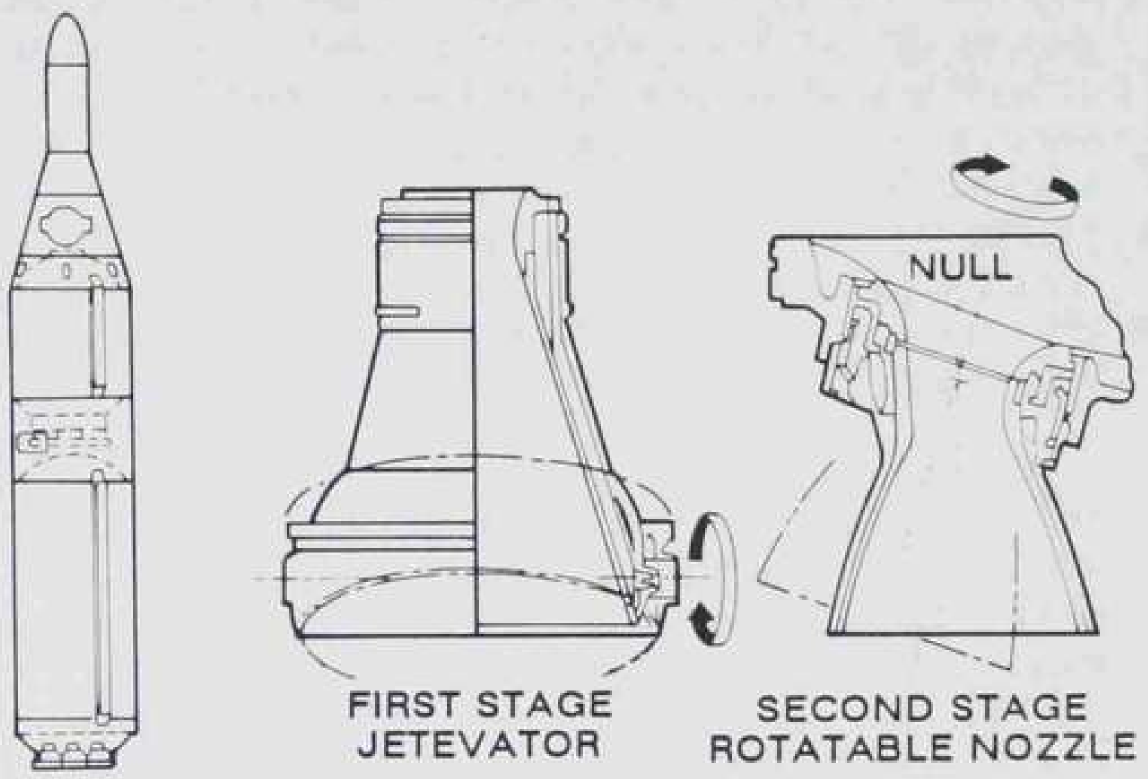
POLARIS A2

To achieve a 1500 nm POLARIS A2, the most obvious way would be to make some components of the missile lighter and improve the performance of the propellants. After evaluating the most practical approach for maximum improvements with minimum risks, it was decided to concentrate on the SS, reducing its associated inert weights and improving the specific impulse of the SS motor. Reduction of SS inert weight would result in eight times more increase of a range increment than a similar reduction in FS.

The Alleghany Ballistics Laboratory (ABL) under the operation of Hercules Powder Company, took on the development of an improved propellant, a cast-in-case double base (nitrocellulose/nitroglycerin) propellant to which was added the aluminum fuel and ammonium perchlorate oxidizer.

The motor chamber's weight was reduced by the use of a glass filament-wound approach versus steel. It consisted of continuously wound glass fibers with epoxy resins.

With the improvement in propellant in the SS came an increase of thrust plume temperature. There had been previous problems with jetevators on A1's; so an alternate TVC system was developed (e.g., rotatable nozzles). This concept employed a unique feature in that the axis of rotation on each of four nozzles was set at an angle and produced pure axial thrust when the nozzle was in the null position. When the nozzle was rotated about its axis, the jet stream was deflected relative to the centerline of the motor, thus permitting TVC with a minimum loss in axial thrust. Two opposite nozzles turning together produced a component of side force in the direction toward which they were rotated. If they were rotated in opposite but equal directions, roll-control torque was produced.



POLARIS A2 TVC

In addition to the SS improvements, the POLARIS A1 FS motor design was lengthened by 30 in. but the same A1 propellant was retained along with jetevators for TVC.

The launch of the first A2X missile at Cape Canaveral on 11 November 1960, signaled the beginning of an extremely successful test program. The entire A2X flight test program consisted of 28 vehicles, of which 19 were successful, 6 partially successful and 3 failures. However, 8 of these A2Xs were reconfigured for the purpose of testing Mk II guidance and RB materials (both for A3X application) and these were fired at various times in late 1961 and during 1962. They had designations such as A2G, A2M, and A2MG.

With the advent of the A2X program came the first experience with flame attenuation of radio frequency communications during the boost phase. The new propellant used in SS motors contained a high percentage of aluminum which caused ionized particles in the exhaust plume.

When this ionized cloud came between the missile and the ground-based radio frequency facilities, blackout of telemetry, destruct, and tracking functions occurred. The problem was solved by relaying to down-range stations in front of the missile and the ionized plume.

The first successful submerged launch of the POLARIS A2 came from the USS Ethan Allen (SSBN-608) on 23 October 1961 off the Florida coast.

It should be noted here that the USS Ethan Allen, (SSBN-608) operating in the Pacific as a unit of Joint Task Force 8 — Operation Frigate-Bird," fired the only nuclear-armed POLARIS missile ever launched on 6 May 1962. A POLARIS A1 missile was launched from the USS Ethan Allen (SSBN-608) while submerged in the Pacific, and its nuclear warhead was detonated over the South Pacific at the en of its programmed flight. The shot was made duri the 1962 atomic tests and hit "right in the pickle ba rel." The captain of the 608 was Paul Lacy, ar ADM Levering Smith was aboard. To date, this is th only complete proof test of a U.S. strategic missil With the ban on atmospheric testing, the chances another similar test are remote.

On 26 June 1962, the POLARIS A2 began its initi operational patrol when the USS Ethan Allen de parted Charleston, South Carolina.

POLARIS A3

Now it was time to bring forth the 2500 nm POLARIS A3. The 2500 nm range would make POLARIS, operating in both the Atlantic and Pacific, a true global deterrent plus provide greater sea room and operating area to offset the expanding Soviet antisubmarine capabilities. Another consideration for the POLARIS A3 was the need for improved accuracy from the longer-range and increased-penetrability capability against the Soviet's antiballistic missile defense.

To meet these objectives, the A3's design included multiple RB concepts, improved guidance, fire control, and navigation systems; penetration aids (Pen-Aids); and missile trajectory shaping techniques. New technologies were also considered such as, advancements in propellants, electronics, materials, and TVC concepts.

As mentioned previously, several A2X test vehicles were launched in late 1961 and 1962 for the purpose of testing improved guidance systems and RBs for the A3. So even before POLARIS A2 became operational, POLARIS A3 design and component testing was underway.

The design of the POLARIS A3 was restricted in size by the volume available in the submarine's (SSBN) launch tube. Thus the A3 was limited to being approximately the same size as A2 but was to fly 2500 nm versus 1500 nm. Therefore, the A3 was basically a new design missile, rather than an evolution, as was A1 to A2.

Two POLARIS A1 missiles, A1X-50 and 51, were reconfigured for tests of an advanced TVC system based upon injection of high-density fluid (Freon 114) into the exit cone of the nozzle, creating a shock pattern and causing the main exhaust stream to deflect. On 29 September 1961, this system was successfully demonstrated during SS flight and, after a second test 2 months later, was chosen as the baseline TVC system for the A3 SS. The outstanding advantages of the fluid injection system were its low effective inert weight, its insensitivity to the propellant flame temperature, and the negligible constraint imposed on primary nozzle design. At this time, the rotatable nozzle concept was retained for the FS.

Guidance required significant development with the systems weight and volume allocation set at less than half that allowed in the earlier A1 and A2 missiles. Increased component accuracy was also a requirement at the longer A3 ranges. To demonstrate the effectiveness of the new inertial instruments and a simplified computer mechanization, the proposed system was flown with excellent results on seven special A2 tests during a 1-year period, starting in November 1961.

An attempt was also made to obtain data on RB materials. A special A2 flight test missile evaluated the nylon-phenolic ablative heat shield which has been selected following an extensive ground test program.

Also included in the innovations which provided the major gain in performance of the POLARIS A3 over the A2 were improvements in propellants, chamber materials, and alternate velocity control techniques. The FS chamber material was changed from steel to high-strength resin-impregnated glass roving, and the propellants were changed to formulations with higher specific impulse and density. Another significant development was the replacement of the single warhead with three RBs at fixed spacings for more efficient target coverage and reduced vulnerability to possible defenses.

The first A3 flight test was conducted at Cape Canaveral on 7 August 1962. Considering the challenge and redesign involved in the development of the A3 missile, it was not until the seventh development flight that complete success was achieved. It was during the A3 development program that the concept of incorporating production components/processing was first introduced into the development phase of a program (A3X-18). (This approach was later to be called "production disciplines.")

During June 1963, the A3X was successfully tested for the first time in a tube-launched firing at sea from the USS Observation Island (EAG-154). The first launching of a POLARIS A3 missile from a submerged submarine, the USS Andrew Jackson (SSBN-619) (a scheduled A2 SSBN), took place on 26 October 1963.

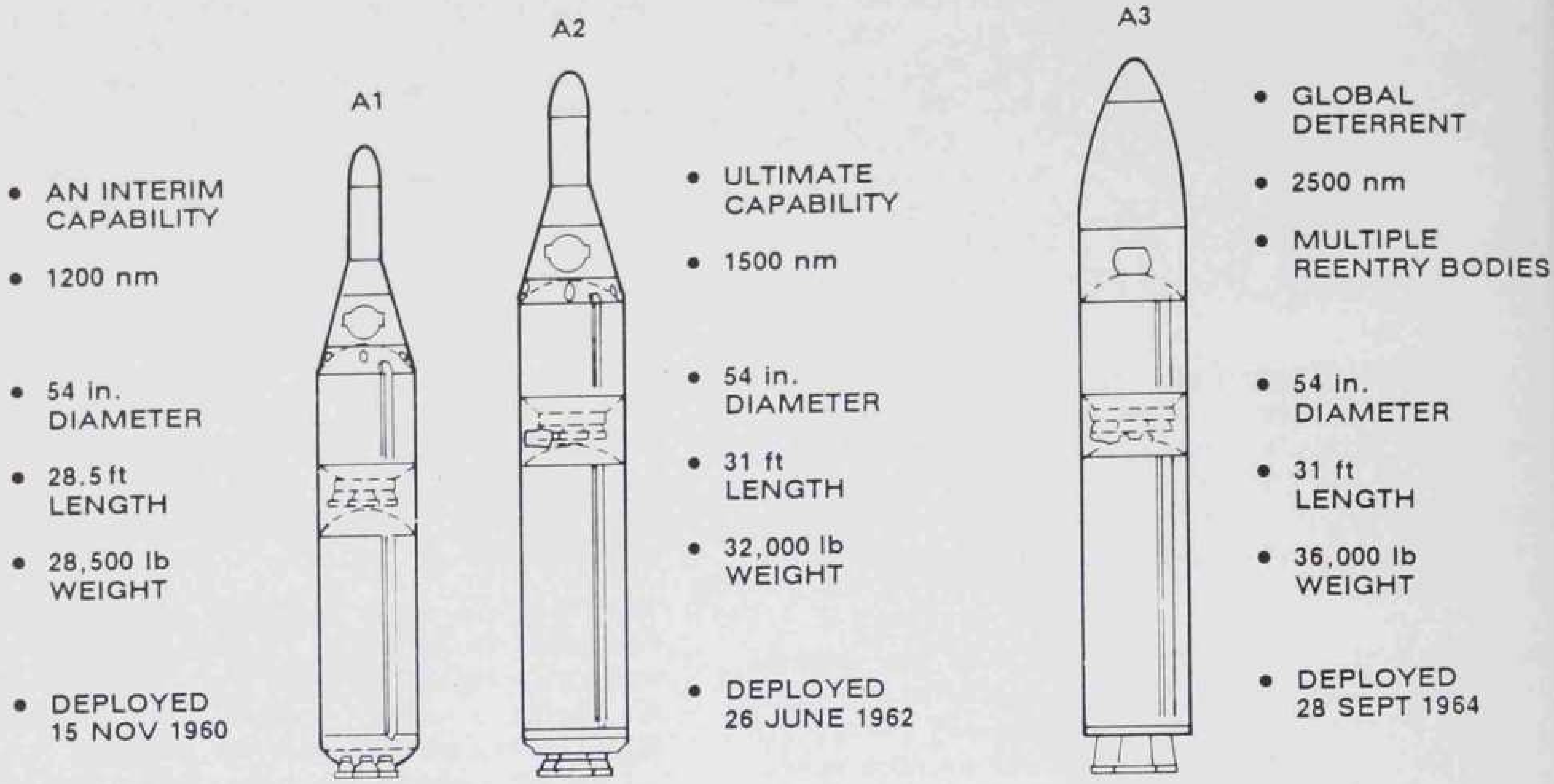
The A3X flight test program started on 7 August 1962 and was completed on 2 July 1964. There were a total of 38 flights, of which 20 were successful, 16 partially successful, and 2 failures.

The POLARIS A3 missile became operational on 28 September 1964 when the USS Daniel Webster (SSBN-626) began her initial operational patrol with 16 A3 missiles. And another milestone was reached on 25 December 1964 when the USS Daniel Boone (SSBN-629) departed Apra Harbor, Guam and began the first Pacific Ocean operational patrol. With all the Eurasian land mass covered by the 2500-mile range of the POLARIS A3 missile, the FBM System became, for the first time, a true global deterrent.

It was during this 1961 – 1964 time frame that other facets of the FBM Weapon System were also coming to maturity.

As pointed out before, 41 SSBNs were authorized by 2 July 1962, with the entire force to be operational by 1967. The fourth SSBN tender was authorized by 10 August 1962.

* But a function of the trajectory & launch point.



FBM System — Global Deterrent

RADM Ignatius J. "Pete" Galantin relieved Vice Admiral (VADM) William F. "Red" Raborn, Jr., as Director, SPO, on 26 February 1962.

On 23 April 1962, the DoD announced the selection of various facilities planned for POLARIS support in the Pacific area. Puget Sound Naval Shipyard at Bremerton, Washington, was selected as FBM submarine overhaul facility; the Naval Ammunition Depot at Bangor, Washington, was selected for the POLARIS Missile Facility, Pacific (POMFPAC); Pearl Harbor, Hawaii, was chosen as the location of the crew training facility. POMFPAC construction started on 5 March 1963 and was commissioned on 11 September 1964.

On 28 March 1963, the DoD announced deployment of first of three FBM submarines in the Mediterranean and that these three would come from those operating from Holy Loch, Scotland. On 14 April 1963, the USS Sam Houston (SSBN-609), first POLARIS submarine assigned to Mediterranean patrol, visited Izmir, Turkey. This was the first foreign port, other than Holy Loch, visited by an SSBN.

The USS Proteus (AS-19) arrived at Rota, Spain on 24 February 1964 to be the FBM submarine tender at this second advanced FBM anchorage site for Squadron Sixteen. Holy Loch had been the first site. The USS Lafayette (SSBN-616) arrived at Rota on 2 May 1964 to become the first SSBN assigned there

The third FBM advance anchorage site, at Apra Harbor, Guam, became operational on 1 December 196 with USS Proteus (AS-19) as the FBM tender. Th USS Proteus (AS-19) had opened all three FBM anchorage sites.

An FBM Training Center, Dam Neck, Virginia, wa opened on 24 September 1964, with the dedication o Raborn Hall, named after VADM William F. "Red" Raborn, the first Director of SPO.

It was also during this time span that the concept o Pen-Aids for the FBM RBs came under consideratio several times to counter potential improvements in the Soviet's ABM Defense System. The first of these Pen-Aids was PX-1 for POLARIS A2 during the 196 – 62 time frame. This was followed by PX-2 fo POLARIS A3 during the 1963 to 65 era. These programs consisted of concept studies and testing. In the case of PX-1, the program proceeded through development and into production. One SSBN load of missiles was deployed with PX-1 Pen-Aids but was offloaded when the perceived ABM threat did no emerge. The range of the A2 was reduced when loaded with PX-1. Offloading restored the A2's capability.

The various Pen-Aid concepts for the FBM system are discussed under the PENETRATION AIDS PROGRAMS section of this document.

It might be pointed out here that, by going to the three-RB concept on A3, the probability of penetration was improved and could be considered as a "penetration concept."

THE UNITED KINGDOM'S POLARIS (A3)

It was also during the "Early Years" time span that the United Kingdom (U.K.) entered into the FBM world.

In December 1962, the then Prime Minister of Great Britain, Mr. Harold Macmillan, met with John F. Kennedy, then President of the United States, at Nassau in the Bahama Islands. They discussed the cancellation of the Skybolt project. Skybolt was a U.S. development project which the U.S. had agreed to share with the U.K. It had been planned as U.K.'s prime deterrent and its cancellation caused the U.K. some concern. At this Nassau meeting, it was agreed that the POLARIS A3P would be made available to Britain in order to maintain the U.K.'s deterrent potential during the years ahead. This agreement became known as the "Nassau Agreement." It eventually resulted in signing of the "U.S./U.K. POLARIS Sales Agreement" in April 1963. It was further agreed that Britain would build its own submarines of their own design, including the nuclear propulsion plant, but would be armed with the POLARIS A3P missile. Britain would also design and construct its own nuclear warheads for the POLARIS missiles.

In January 1963, the U.K. Defense Committee decided that four FBM submarines should be built, with an option on a fifth which was later cancelled. The four submarines in the U.K. POLARIS program are:

Submarine Number	Submarine Name
SSBN-01	HMS Resolution
SSBN-02	HMS Renown
SSBN-03	HMS Repulse
SSBN-04	HMS Revenge

A British Admiralty negotiating team came to the U.S. to negotiate a detailed U.S./U.K. agreement. The POLARIS Sales Agreement was signed on 6 April 1963. Upon approval of this agreement, work began in earnest and continued at an intense pace ever since. VADM R. N. MacKenzie was named the U.K. Chief POLARIS Executive (CPE) and he was authorized to use personnel from the MOD(N) for the production of submarines, ground support, and mechanical and electrical equipment. The Ministry of Public Buildings and Works has prime responsibility for providing facilities ashore for supporting and maintaining the entire system. The Ministry of Aviation has the responsibility, within the U.K., for procurement of the POLARIS missile, including the reentry system and all necessary associated support equipment. It also acts as the U.K. approving authority for the reentry system's warhead. Through the U.K. Atomic Energy Authority, design responsibility for the U.K. warhead is in the Aldermaston Atomic Weapons Research Establishment (AWRE), under the direction of the Ministry of Aviation.

To ensure cooperation and coordination, a Joint U.S.-U.K. Steering Task Group and a Joint U.S.-U.K. Reentry System Working Group were formed. These were parallel structure groups to those in the U.S. FBM Program.

Contracts were released to British industry for various parts of their weapon system. Among them were:

a. Vickers Ltd. (shipbuilder) — for the launching system

b. BAC — for the POLARIS missile, test equipment, ULCER

c. GEC — for fire control and test instrumentation subsystem

d. Elliott & Sperry — for the navigation system

e. EMI — for the weapon control subsystem simulator

f. Vickers, Barrow & Cammell Laird, Burkenhead — shipbuilder for the submarines.

It might be noted here that the HMS Resolution (SSBN-01) deployed with POLARIS A3P on its first operational patrol in June 1968.

HIGHLIGHTS (1961 - 1964)

Some of the following highlights were extracted from "POLARIS Development Highlights 1956 to 1964" by M. E. Murphy RADM (ret) Senior Staff Engineer, LMSD dated 1964 (reference 1) and SSPO's document "FBM Facts/Chronology — POLARIS, POSEIDON, TRIDENT," dated 1982 (reference 5).

21 Jan 1961	The USS George Washington (SSBN-598) arrived at New London, Connecticut, having completed her first patrol. She had been gone 67 days and had set a new record for length of time submerged — 66 days, 10 hours. She came alongside the tender, USS Proteus (AS-19), which was to complete her first FBM submarine upkeep in the stateside port before sailing to Holy Loch, Scotland.
27 Jan 1961	LMSC published "The POLARIS A3 Missile Development Plan" (LMSD/474335), providing for development, test, and delivery of initial shipfill in July 1964.
7 Feb 1961	LMSD received the Navy Certificate of Merit for excellence in the development of POLARIS, 3 years ahead of schedule; L. E. Root and W. M. Hawkins received the Navy Distinguished Public Service Award; and H. J. Brown, S. W. Burriss, F. J. Bednarz, and D. A. Stuart received the Navy Meritorious Public Service Award. The personal awards were presented by VADM William F. "Red" Raborn, USN.
1 Mar 1961	First USS Observation Island (EAG-154) — launched A2X Missile (A2X-7). Successful flight.
12 Jun 1961	LMSD became LMSC with L. E. Root as President, and with S. W. Burriss as Vice President and General Manager of MSD.
9 Jul 1961	The USS Robert E. Lee returned from patrol and came alongside the USS Proteus (AS-19) at Holy Loch. She had established a record by staying submerged and completely sealed for 68 days, 4 hours, 15 minutes.
29 Sep 1961	The first missile with fluid injection TVC (A1X-50) was successfully flight tested at AMR.
23 Oct 1961	The USS Ethan Allen (SSBN-608) launched A2X-4 for a 1399 nm successful flight, the first submerged launching (from a submarine) of an A2 missile.
16 Nov 1961	Development had begun on Pen-Aids PX-1 program plans were submitted to SP on 1 November. Contractual go-ahead was expected by 20 November for PX-1. PX-1 flight test was scheduled for July 1962.
7 Dec 1961	Last production model of POLARIS A1 delivered.
26 Feb 1962	Rear Admiral Ignatius J. "Pete" Galantin relieved VADM William F. "Red" Raborn, Jr., as Director, Special Projects.
1 Mar 1962	First successful flight of Mk 2 guidance system on A2G-5 (A3X-27).
3 Apr 1962	First A2P SDAP (now DASO). A2P-3 was fired from SSBN-609 and made a successful flight.
6 May 1962	USS Ethan Allen (SSBN-608), operating in the Pacific as a unit of Joint Task Force 8, successfully fired a POLARIS A1 missile with a nuclear warhead. Successful nuclear detonation achieved.
26 Jun 1962	The USS Ethan Allen (SSBN-608) left Charleston, South Carolina, on its critical operation patrol with the first boatload of POLARIS A2 missiles.
7 Aug 1962	The first A3X missile (A3X-1) was launched from AMR. It was a partial success.
10 Aug 1962	First successful flight (A2TF-2) of Pen-Aids PX-1 equipment, with good test results.
11 Feb 1963	A3X-7, the first fully-successful A3X missile, was launched from AMR.

15 Mar 1963 — The USS Hunley (AS-31) relieved the USS Proteus (AS-19) at Holy Loch, Scotland.

26 Sep 1963 — First steam-eject launch of a POLARIS missile from the USS Observation Island (EAG-154) at sea off Cape Canaveral, Florida. Prior EAG Launches used high-pressure air. Steam ejection was to be incorporated on SSBN.

16 Nov 1963 — President John F. Kennedy watched a successful launch of a POLARIS A2 missile from the USS Andrew Jackson (SSBN-619). He saw the shot from the deck of the USS Observation Island (EAG-154).

1 Apr 1964 — First PMR flight of an A3X missile (A3X-53). EAG-launched, it was successful.

1 Apr 1964 — The USS Holland (AS-32), the second submarine tender built from the keel up for the support of FBM submarines, arrived at Rota, Spain, to relieve the USS Proteus (AS-19).

20 Apr 1964 — The USS Henry Clay (SSBN-625) successfully launched a POLARIS A2 missile from the surface. This was the first demonstration that POLARIS submarines could launch missiles from the surface as well as from beneath the ocean. Thirty minutes earlier, the USS Henry Clay (SSBN-625) successfully launched an A2 missile while submerged.

25 May 1964 — The USS Lafayette (SSBN-616) arrived at Rota, Spain, to become the first FBM submarine to use the second advanced FBM anchorage. Lafayette was the first submarine assigned to Squadron Sixteen.

2 Jun 1964 — The USS George Washington (SSBN-598) returned to Charleston, South Carolina, to off-load missiles in preparation for overhaul at General Dynamics, Electric Boat Division, shipyard in Groton, Connecticut. This ended the initial deployment of the first FBM submarine, which began in November 1960.

21 Aug 1964 — The USS Daniel Boone (SSBN-629) reported to the Pacific Fleet, becoming the first FBM to be permanently assigned to the Pacific.

11 Sep 1964 — POMFPAC was commissioned at the U.S. Naval Ammunition Depot, Bangor, Washington. The SECNAV, Paul H. Nitze, was principal speaker.

24 Sep 1964 — Raborn Hall was dedicated at the FBM Training Center, Dam Neck, Virginia, named after VADM William F. "Red" Raborn, first Director of SPO.

28 Sep 1964 — The USS Daniel Webster (SSBN-626) left Charleston, South Carolina, to begin her initial deployment. She carried the first boatload of the new and longer-range POLARIS A3 missile.

3 Nov 1964 — The USS John Adams (SSBN-620) left Charleston, South Carolina, to go on operational patrol with 16 POLARIS A2 missiles. Of the SSBNs carrying A2 missiles, she was the last to deploy.

1 Dec 1964 — The third FBM advance anchorage site, at Apra Harbor, Guam, became operational with the USS Proteus (AS-19) as the FBM tender. The USS Proteus (AS-19) has opened all three FBM anchorage sites.

25 Dec 1964 — The USS Daniel Boone (SSBN-629) departed Apra Harbor, Guam, with 16 POLARIS A3 missiles to begin the first operational patrol in the Pacific. The Eurasian land mass was now covered by the 2500 mile range of the POLARIS A3. The FBM Weapon System had become a true global deterrent.

HIGHLIGHTS OF U.K. PROGRAM

Dec 1962 — Meeting between Prime Minister Macmillan and President Kennedy; decision made to use the POLARIS missile in British submarine fleet.

Jan 1963 — Decision that British would build total of four FBM submarines. British technical missions in U.S. for detailed study of American FBM system.

6 Apr 1963	POLARIS Sales Agreement signed, followed by prompt implementation of its terms.	NOTE:	U.K. highlights continue in the 1965 - Early 1971 section of this report.

A2X FLIGHT TEST SUMMARY

A2X General Characteristics

Dimensionally quite similar to A1X except FS is 30 in. longer; weight 32,500 lb; length 31 ft; range approximately 1450 nm (with instrumentation).

First stage (22,400 lb) — Steel motor case; polyurethane propellant (19,200 lb) with ammonium perchlorate (oxidizer) and aluminum additives, ANP 2639AF (same as A1X); jetevators; IS.

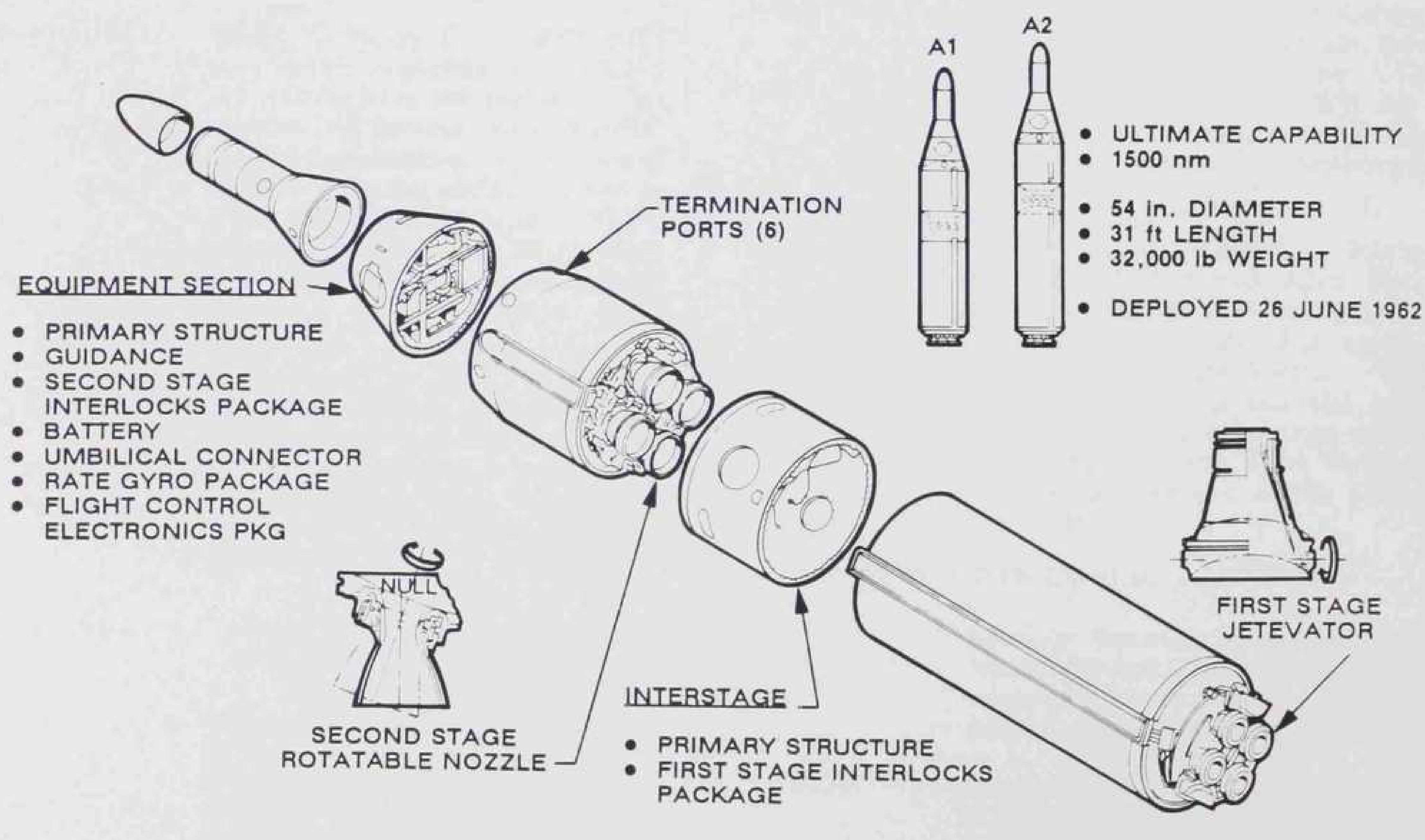
Second stage (9,300 lb) — fiberglass motor case; composite modified double base propellant (7,400 lb), DDT-70; motor designed by ABL; rotating nozzles; Mk I guidance system (235 lb); ES.

A2 Major Development Problems

The A2 missile had considerably less development problems than the A1. The A2, being an extension of the A1 in many aspects, had greater maturity when it entered the flight test stage. With the primary difference in the two missiles being in the SS motor, it was not surprising, however, that some pre-flight problems should arise in that area of the A2. The new rotating nozzles, replacing the A1 jetevators, had a tendency to stick in static motor tests. Considerable effort was expended to correct this fault. Fortunately, by the time A2X-1 was flight tested, the problem had virtually disappeared.

The comparatively few flight anomalies which the A2X experienced were in the main random type failures, but A2X-9 and 22 (jetevator sticking) gave cause for worry. Sensing that the underwater launch environment was again, as in the A1P SDAP firings, causing trouble, Alpha II was initiated at San Clemente Island, California, to investigate A2X aft end hardware, and it got started in August 1961. (Similar to Alpha I, these were Popup launches, some live with cut-grain motors.)

It turned out that A2X-9 and A2X-22 had different modes of failure. The former had excessive jetevator aeromoment due to aerolip jetevator inserts, plus high friction in the jetevator hinge or linkage, which accounted for the jetevator sticking at launch. This situation was improved by reducing the jetevator insert aerolip. A2X-22 had this fix and exhibited no jetevator anomaly at launch. What happened to A2X-22 was a sticking jetevator at 7 sec, probably



POLARIS A2

A2X FLIGHT TEST SUMMARY

Missile Number	Date/ Site	Resume of Results	Success	Partial Success	Failure
1	11-10-60 FP	Successful flight 1414 nm.	X		
2	12-5-60 FP	Successful flight 1369 nm had C-band beacon because Azusa data were being lost (SS flame attenuation).	X		
3	1-10-61 FP	Successful flight 1386 nm.	X		
6	2-6-61 FP	FS igniter malfunctioned, missile blew up on pad, first guided flight aborted. Mk I guidance. (Another 4th of July fireworks reminiscent of AX-21)		X	
7	3-1-61 FP	Successful flight 1386 nm.	X		
8	3-9-61 EAG	Successful flight 1448 nm. First successful A2 guided flight. Mk I guidance.	X		
10	3-15-61 FP	Successful flight 1402 nm.	X		
12	4-11-61 FP	SS failed to ignite, 123 nm. Mk I guidance.		X	
16	5-1-61 FP	Successful flight 1302 nm. Mk I guidance. Antigua MILS.	X		
19	5-8-61 FP	Successful flight 1303 nm. Antigua MILS. Mk I guidance.	X		
9	5-25-61 EAG	FS steel jetevators experienced excessive aeromoment and high friction until 6 sec, destructed 10 sec. (Anomaly probably not due to steel JV housings.) The JV insert aerolip was reduced to correct aeromoment, and fix went into A2X-22.			X
5	6-12-61 FP	Successful flight 1434 nm.	X		
11	6-26-61 EAG	Pitch rate started down at 77 sec, vehicle did not recover, 572 nm. Guidance failure. Mk I guidance.		X	
20	7-13-61 FP	Successful flight 666 nm. Medium-range flight into Grand Turk MILS. Mk I guidance.	X		
21	8-2-61 FP	Successful flight 1300 nm. Antigua MILS. Mk I guidance.	X		
22	8-18-61 EAG	Cracked nozzle exit ring caused JV No. 1 to stick at 7 sec, control lost, destructed 35 sec.		X	
13	10-4-61 EAG	Successful flight 1391 nm. JV's were nulled. Mk I guidance.	X		
4	11-8-61 SSBN 608	Successful flight 1399 nm. First A2 from submarine. Mk I guidance.	X		
15	11-8-61 SSBN 608	Successful flight 1400 nm. Mk I guidance.	X		
23	12-1-61	Successful flight 1481 nm. FP	X	—	—
		Total A2X Flights — 20	15	3	2

NOTES: 1. All flights not marked "Mk I guidance" carried substitute guidance systems.

2. Eight additional A2X vehicles were reconfigured for Mk II guidance and RB material development (for A3X application) and were flight tested during the period from 9 November 1961 to 19 December 1962. They were designated A2G, A2M, or A2MG vehicles (depending on their configuration and objectives). They are recorded in a later section under "Pre-A3X Flight Test Summary."Of these 8 vehicles, 4 were successful, 3 were partially successful, and 1 was a failure. Lumping these 8 with the 20 A2X flights recorded above, the overall score becomes 19 successes, 6 partial successes, and 3 failures.

caused by interference from a cracked nozzle exit ring and possibly complicated by mechanical interference between jetevator and flame baffle. (The cracked nozzle exit ring proved to be a phenomenon associated with a tight clearance in some motors, which was not present in later ones.)

The primary fix to come out of Alpha II firings was to get the jetevators out of the immersed condition at ignition, by "nulling." A2X-13 had the jetevators nulled and it was successful (4 October 1961). Also, closer attention to jetevator-flame baffle clearances and removal of nozzle plugs were by-products of Alpha II and related static motor tests. They seemed to have a beneficial effect.

Within a month after A2X-13, there were two submarine launches (A2X-4 and A2X-15), both carrying Alpha II fixes and both successful, which indicated strongly that A2 development was on firm ground. Subsequent performance confirmed this.

PRE-A3X FLIGHT TEST SUMMARY

As mentioned previously, eight additional A2X vehicles were used as test beds for A3X development (Mk II guidance and RB material). In addition, two A1Xs were flown using fluid injection on the SS motor for TVC.

Fluid Injection TVC Flights (for A3X Development)

Missile Number	Date/ Site	Resume of Results	Success	Partial Success	Failure
A1X-50	9-29-61 FP	Successful flight, fluid injection TVC in SS (first such test in U.S., probably in world). Nitrogen/Freon system. Not thrust terminated in order to prolong TVC performance.	X		
A1X-51	12-5-61 FP	Successful flight, same fluid injection TVC. Was thrust terminated this time in order for RB to function normally. Used only one third of Freon, prompted decision to reduce Freon volume considerably in A3X.	X		
		Total Fluid Injection TVC Flights (A1X) — 2	2	0	0

Mk II Guidance and RB Material Flights (for A3X Development)

Missile Number	Date/ Site	Resume of Results	Success	Partial Success	Failure
A2G-1 (A2X-14)	11-9-61 FP	Loss of control, No. 4 SS nozzle, destructed 75 sec. Mk II guidance development.		X	
A2G-2 (A2X-17)	1-23-62 FP	SS case ruptured 82 sec, 367 nm. Mk II guidance development.		X	
A2G-5 (A2X-27)	3-1-62 FP	Successful flight 1715 nm. First full test of Mk II guidance.	X		
A2M-3 (A2X28)	3-30-62 FP	Yaw-roll gyro failed to spin at launch, destructed 18 sec. RB material development. Test of nylon phenolic RB aborted.			X
A2MG-1 (A2X-18)	5-3-62 FP	Successful flight 1826 nm. Mk II guidance and nylon phenolic RB bi-conical shell.	X		
A2MG-2 (A2X-30)	6-4-62 FP	Electrical failure caused SS No. 4 nozzle hardover, lost control, destruct unsuccessfully attempted 90 sec. Nylon phenolic RB shell and Mk II guidance development. (aborted).		X	
A2M-4G (A2X-29)	6-29-62 FP	Successful flight 1875 nm. Nylon phenolic REB shell and Mk II guidance development. RB data not obtained due to unsatisfactory tracking of RB.	X		
A2G-4 (A2X-24)	12-19-62 FP	Successful flight 1414 nm. Mk II guidance development. Final Mk II block 01 guidance — successful.	X		
		Total A2G/M/MG Flights — 8	4	3	1

NOTE: Sufficient data were obtained on fluid injection TVC and Mk II guidance to proceed into A3 development. However, only one flight (A2MG-1) out of four provided flight characteristic of nylon phenolic an RB oblative shell. Proceeding with it into A3 development was a bit "iffy," but it eventually was proven to be a good decision.

A3X FLIGHT TEST SUMMARY

A3X General Characteristics

Length 373.5 in. (1.5 in. longer than A2X); weight approximately 36,500 lb; diameter 54 in.; range approximately 2000 nm (with instrumentation).

First stage (24,600 lb) — Fiberglass motor case; Nitro plasticized polyurethane propellant (21,800 lb), ANP 2969 (Aerojet); rotating nozzles; IS.

Second stage (10,800 lb) — Fiberglass motor case; composite modified double base propellant (9,000 lb), EJC (Hercules); fluid injection TVC; Mk II guidance system (80 lb); ES.

Reentry system — three RBs which tilt outboard and are ejected by small rocket motor. TT thus eliminated.

Because of the number of anomalies in the A3X flight test program, the anomaly and corrective action for each flight is shown in the A3X Summary.

There were a total of 38 A3X flights of which 20 were considered successful, 16 partially successful, and 2 failures. Of the 20 successes, only 15 had successful RB operation and ejection. It was only until the 15 A3X flights that the program began to have a continuous series of success.

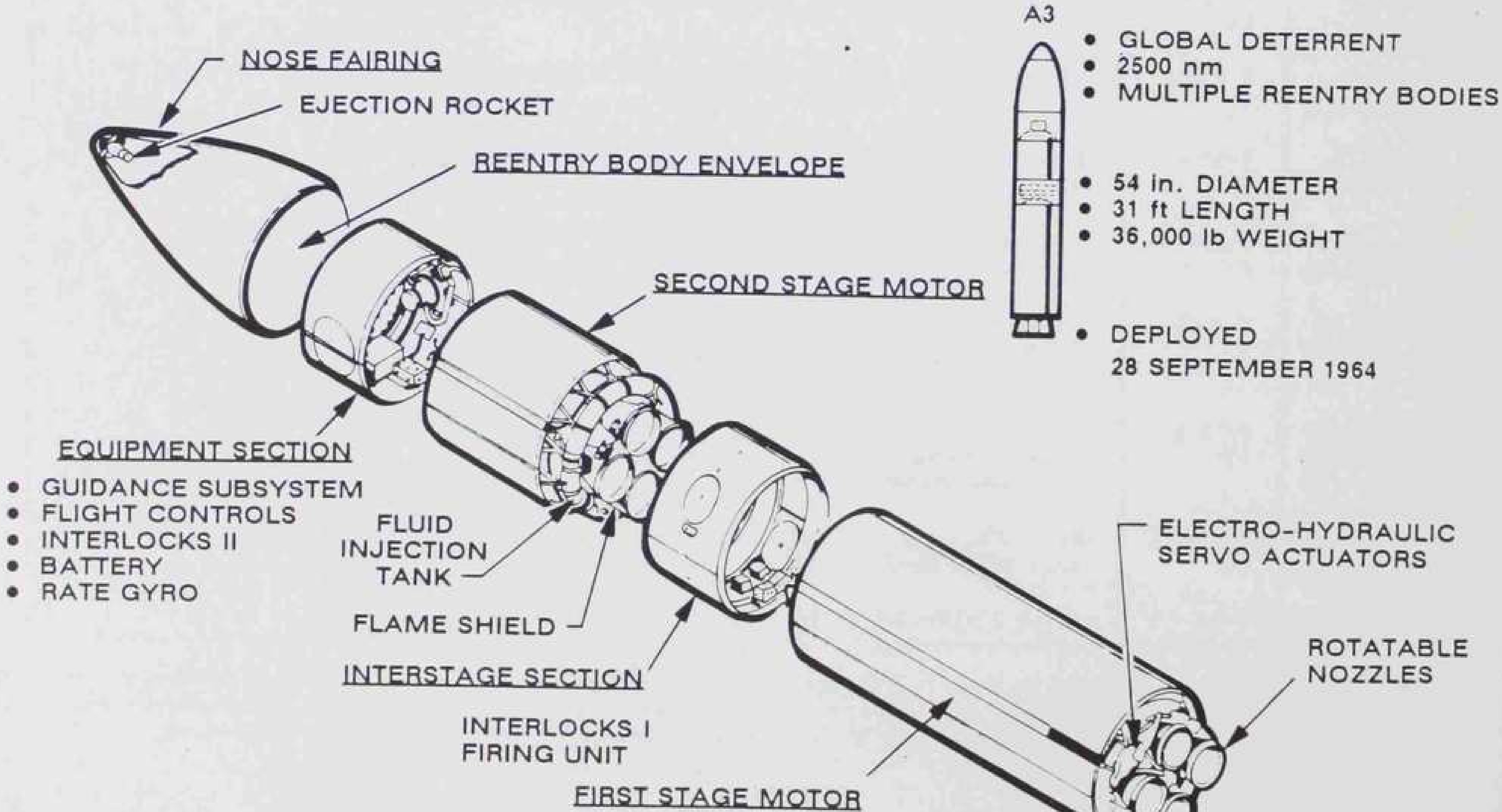
A3 MAJOR DEVELOPMENT PROBLEMS

Propulsion — First Stage

The FS at Aerojet was plagued, in early phases, by a most negative reaction between the propellant and the nozzles. The inability to retain a set of nozzles for full duration in static firings delayed the beginning of an examination of nozzle rotation.

By using a "cooler" propellant ANP 9969 (about 6000°F flame temperature) and by beefing up the nozzles to massive proportions, using tungsten throats, the nozzle erosion problem could be solved, but at the loss of some 90 nm in range.

The penalty of heavier nozzles was intolerably high torques. This was gradually solved by improved nozzle design and, more importantly, by doubling the power of the hydraulic actuation system. The original Mod V actuation system was entirely inadequate, and it gave way to the Mod VI, ending up with the Mod



POLARIS A3

VIB as the final design. This, of course, added even more weight.

Nozzle and actuation problems were overcome, by brute force, and the FS motor for A3X-1 performed adequately. Except for one aft end blow-out (A3X-4) and an occasional sticking nozzle (A3X-42 and A3X-46 are cases in point), the FS motor had turned in a good flight record. Late in the program, A3X-46 was lost at 25.5 sec because of a stuck nozzle. This generated an extensive program of investigation at Aerojet and MSD. Mechanical interference between aft end cables and nozzles, under certain tolerance conditions, was found to exist and could account for some of the nozzle sticking, but the incidence of such a situation has been deemed too slight to warrant undertaking design changes involving cable rerouting. Likewise, no strong case had been made for making changes to the nozzle itself.

Propulsion — Second Stage

Early in the game, ABL had a series of propellant problems involving base grain processes, overly rich solvent mixtures, and sensitivity in the slurry mix process, which led them to drop both their favorite propellants. A new candidate was finally developed. It was a composite modified double base propellant designated EJC. This turned out to be quite satisfactory in the A3X flight test program. However, in production motors, it developed low-density (porosity) problems which became a matter of concern in the spring of 1964. Associated with low-density propellant was a case bond separation problem. A third problem that came to light was a seeming lack of structural integrity in nozzles built by Kaiser. May 1964 static motor tests, however, indicated that these three problems were either not as severe as initially thought or that remedial action (processing control) had a salutary affect.

Reentry Body Material

Selection of material for the RB shell consumed considerable pre-A3X time and effort. Pyrolytic graphite was originally planned for this purpose, with beryllium, as a backup. However, the development of this new form of graphite did not proceed fast enough to meet the A3X time scale, and it was sidetracked in favor of nylon phenolic. While nylon phenolic was not a good ground plane and caused degradation of telemetry transmission, it was satisfactory in other respects. It was flight tested in the A2M and A2MG program. Unfortunately, flight results were rather meager, due to flight failures and data acquisition troubles. The small amount of data obtained was favorable to nylon phenolic; therefore, it was used for the A3X, although with a lower confidence level than desirable. It turned out well.

Fluid Injection TVC

A3X-1 carried a nitrogen-Freon TVC system (fluid injection) in which nitrogen in a high-pressure tank (5000 psi) was used to pressurize Freon (at 750 psi) in aluminum tanks. High-pressure fluids are not desirable items onboard ships; hence, the nitrogen tank gave way to a gas generator system in the Mod I TVC. It was flown on A3X-2 and nine other flights.

The Mod I TVC system exhibited a variety of troubles. Out of 8 flights, in which it had an opportunity to function, there were 5 failures, attributable to different anomalies of the following categories: blocking valve, ruptured manifold, firing unit, plugged manifold, and regulator.

Fortunately, the Mod II TVC system came along and its incorporation in A3X flights was accelerated to the extent that all flights after A3X-11 (except A3X-14) carried the Mod II. This switch completely solved the problem. In the Mod II, the Freon tank is in one piece (horseshoe-like) and is capable of being opened up enough to slip over the nozzles for installation on the motor. With only one tank, the flow equalizer was not needed. The Mod II TVC has proved to be highly reliable.

Exploding Bridgewire Firing System

The flight of the A3X-3 introduced a new problem of major proportions. Failure of the NF to separate was traced to a faulty exploding bridgewire firing unit, casting suspicion on this new system. This set in motion a series of investigations and tests. In tests at Sunnyvale, corona and arcing were observed in and around the firing unit, which led to a thorough investigation of all available firing units. In some cases, voids were noted in the potting compound, as well as poor adhesion of potting compound to circuit cards. These disclosures pointed up part of the problem and dictated steps to improve fabrication and inspection methods. Tests were also conducted at CALAC's altitude chamber at Rye Canyon. Although initial tests were negative, it was decided to adopt, as standard procedure, simulated altitude tests of firing units in the future. This decision was made after A3X-6 confirmed that there was a firing unit problem. It was also decided, as an interim measure, to insert a silicone rubber washer and silicone grease in the ordnance header of the exploding bridgewire connector. The purpose of this was to reduce free volume and help eliminate arcing. This interim fix was flown on A3X-7, 8, 9, 11, 14, and 18 without firing system malfunction.

The above fix proved to be an effective stopgap. However, permanent redesign measures were indicated and a task force was established. There evolved from this effort a "standard firing unit" to take the place of six different configurations in the missile. Important design features of the standard firing unit were pressure sealing as a measure against arcing, improved packaging, and better servicing features. A3X-27 was the first to carry the standard firing unit. It had a 2 pin connector. A coaxial (1-pin) connector was also being worked on. It was designed to increase pin-to-case distance and thus reduce further the possibility of arcing. Also, a positive pressure seal was in the back shell of the coaxial connector.

The coaxial (1-pin) connector with the above features was added to the standard firing unit later in the A3X series. It was first carried in A3X-38. No failure resulted. In fact, there were no exploding bridgewire firing system failures after A3X-6 where standard firing units were used. (There was one failure because of a non-standard unit.)

Computer Launch Interference Problem

A3X-14, which was launched from EAG-154, suffered "brain scrambling" of its guidance computer, resulting in early dumping of the missile (command destructed at 17 sec). This anomaly was given the code name of CLIP. The phenomenon was found to occur at the time of umbilical disconnect and to be generated at the missile/ground support interface, namely the main umbilical, by reason of a combination of two causes:

a. Separation of umbilical pin contacts resulted in repeated current interruptions during the retraction phase, which caused high frequency interference to be induced upon adjacent guidance control and signal lines.

b. Umbilical shield grouping and termination provided a path (magnetic coupling) for interference to the guidance control and signal lines.

The result of this interference was the introduction on guidance lines of false signals which produced erratic and unpredictable computer operation.

As a temporary fix for upcoming flights, all circuits to the missile, except "launch first motion," were disconnected prior to umbilical separation; also a so-called "T_0 circuit shorting switch" was added. These measures served to reduce radio frequency interference and electrical transients which in turn disturbed the computer.

Before the temporary fix was tried out, Project CLIP had embarked on extensive tests and the development of more sophisticated changes to combat the problem. Coming out of this effort were several recommended changes. Not all were approved for use but the following principal changes were incorporated in the tactical prototype design (A3X-41 and up):

a. Provide tinned copper braid for radio frequency shielding on all ignition system wiring in ES and NF (to prevent induction coupling into other systems)

b. Separate ignition system wiring from guidance wiring (to reduce coupling between systems)

c. Provide new main umbilical assembly with shields regrouped and reterminated, and provide positive shield ground between missile and support equipment (to separate "noise producing" circuits from sensitive signal lines).

d. Grounding strap added, aft end of the missile to SSBN structure, which separates at launch.

In addition, other shielding and wiring changes were made. Also MIT developed a new computer clock "stick," but it was not incorporated. SPALT 3192 was prepared by General Electric which would disconnect heater, blower, and fuze set circuits prior to main umbilical disconnect. It too was not considered necessary in view of other corrective measures, and was not implemented.

The CLIP changes apparently had been adequate since no computer "brain scrambling" has been in evidence since A3X-14.

Reentry System

The A3X Reentry System had a series of problems which required a major effort to correct. For one, the heatshield (between ES and RB structure) lacked structural integrity. On A3X-33 it failed, no doubt due to the thermal environment created by the RB rocket blasts, which were more severe than originally calculated. The severe environment was confirmed in heatshield tests at Rye Canyon, under simulated altitude conditions. Deriving from these and other tests, extensive modifications were made to the heatshield to make it stronger.

It was also found that RB cabling was vulnerable to aerodynamic heating (after NF ejection), plus gas flow and RB rocket blast effects. All of these effects conspired to raise the local heat to 800°F or more. Another "Hot Head" operation got underway and formulated corrective action. This consisted of relocating cabling, rerouting it, and using increased thermal protection, including flexible steel tubing on the cable in certain critical areas.

On A3X-15, RBs B and C did not separate on command, probably due to defective 7 grain FLSC. For succeeding flights, another FLSC lot was used. The casualty did not reappear until A3X-36 when RB C separated several seconds late, again attributed to an FLSC malfunction. Finally on A3X-38, two RBs failed to separate. Before this point in time, it had been decided to consider shifting from 7 grain FLSC to 9 grain mild detonating fuze (MDF), the Dupont trade name being "primacord." The 9 grain MDF would apply more explosive force at the point of separation. Satisfactory tests were run at Santa Cruz on 9 grain MDF and it was incorporated in A3X-39 and succeeding flights, together with modified separation rings. (A shield was added to contain the larger explosive force and protect adjacent RBs.) These changes proved effective, since no separation failures in this mode occurred in subsequent flight tests.

Another RB problem concerned improper action of the tilt out mechanism. This mechanism underwent several minor design changes which corrected the faulty operation.

The last RB problem, as of July 1964, developed on A3X-60 and on a demonstration and shakedown operation (DASO) flight, A3P-4. The STAS was not received by the RBs due to shorting. To correct this, isolation resistors were added in STAS lines, in arm control lines, and in the velocity sensor 30v line.

A3X-10 functioned satisfactorily with these fixes which were incorporated on all future flights.

Yaw Instability at Launch

A3X-55 demonstrated a yaw instability problem. It stabilized in pitch and roll 6.4 sec after ignition but never stabilized in yaw (a roll-out maneuver of over 170 deg was a contributing factor). Control was lost and the missile was dumped when the aerodynamic upsetting moment became greater than the control moment. This was at 21.1 sec.

Initial launch conditions on this particular flight were most unusual in regard to yaw and roll attitude. As designed, the missile could not accept significant translational velocities along the guidance Y-Axis prior to the time guidance begins issuing commands after ignition. The seat of the trouble was in the excessive size of the yaw command storage register (RCY), which had a capacity of storing approximately 170 pulses, amounting to 11.7 deg. In A3X-55's flight, the launch environment caused a rapid saturation of this register. After the guidance began issuing commands, approximately 11.7 deg of yaw commands were issued which was sufficient to drive the missile into a diverging yaw oscillation.

A guidance fix was selected as being the simpler and more logical. The guidance changes involved a minor modification to one computer "stick" (electronic module) and a major change to another. These changes reduced the amount of storage in the RCY register by a factor of 32, making its capacity roughly 5 pulses or a fraction of a degree.

A3XD-60 flew with the above guidance fix, under launch conditions similar to A3X-55, and experienced no trouble. The change was programmed into succeeding missiles.

For information relating to other manufacturing and/or Fleet Operational problem, see reference (2), "Highlights of the Polaris Engineering and Manufacturing Effort," LMSC/D053613.

A3X FLIGHT TEST SUMMARY

Missile Number	Date/ Site	Major Anomaly	Corrective Action
1	8-7-62 FP	No. 2 SS nozzle ejected 8 sec after ignition, control lost 170 nm. (Also, nose fairing (NF) failed to separate.) Nitrogen/Freon TVC.	Nozzle boss redesigned to preclude gas leakage.
2	9-6-62 FP	SS TVC blocking valve malfunctioned, nozzle No. 2.76 nm. Also SS motor failure at 3.3 sec, possibly due to violent maneuvers. Mod I TVC.	Added 3v bias to servos; earlier TVC activate.
3	10-5-62 FP	NF did not separate, firing unit malfunctioned. Destructed 90 sec. Mod I TVC.	Revised inspection and manufacturing techniques of firings units (to be tested at altitude); hole cut in fairing for mating.
4	11-5-62 FP	FS motor aft dome ejected at 28.6 sec. Mod I TVC.	Used motors with reversed port reinforcements (doilies) on A3X-8 and A3X-9 and subsequent vehicles.
5	11-17-62 FP	SS TVC manifold ruptured, pressure lost. Destructed 78 sec. First guided flight. Mod I TVC. Mk II guidance system on this and subsequent flights (except A3X-7).	Manifold wall thickened interstage bracketry beefed up to preclude impact damage from loose hardware.
6	12-6-62 FP	SS TVC did not activate, firing unit malfunctioned. Command destruct failed. SS out of control but spin stabilized in northeast direction, landed 150 nm east of Savannah (nozzle No. 4 restrained 1 sec prior to SS ignition). Mod I TVC.	Used silicon grease in exploding bridgewire connectors; tightened inspection of firing unit manufacturing added altitude environment to firing units tests.
8	2-7-63 FP	False inhibit signal at NF separation, precluding RB separation. Missile flew full distance 1809 nm. (Nozzle No. 4 restrained 1 sec prior to SS ignition, as in A3X-6). Mod I TVC, PX-2(D).	Deactivated inhibit signal pending determination of fix.
7	2-11-63 FP	None. 1860 nm. (However, no RB data, also heatshield failed at second separation.) Mod I TVC. First warhead flight. Substitute guidance system.	None.
9	2-11-63 FP	SS TVC restricted, possibly by plug. (Afterwards, SS nozzle No. 3 throat ejected 80 sec.) Destructed 90 sec.	Improved inspection.
11	3-19-63 FP	Improper pressure regulation, SS TVC (Mod I). Destructed 115 sec.	None. Mod II TVC was incorporated in A3X-18, A3X-20, and up (all except A3X-14).
18	4-8-63 FP	Short in ignition inverter output preventing RB separation. Missile flew full distance 2139 nm. (High first separation perturbation.) First Mod II TVC. First tactical prototype except RB support structure and ES.	Increased protection on inverter output wiring.
14	4-10-63 EAG	Guidance computer disturbed ("brains) scrambled" at umbilical disconnect, control lost, destructed 17.3 sec (intermittent loss of No. 4 nozzle feedback during tube travel). Last Mod I TVC flight. Mod II thereafter, first tube launch.	This generated Computer Launch Interference Project (CLIP). (In time, many changes resulted.) As temporary fix, all umbilical wires except LFM and To were opened prior to umbilical disconnect.
20	4-26-63 EAG	SS Nozzle No. 4 throat ejected 75 sec, TVC pressure lost due to abnormal environment, destructed 143 sec. First tube launch of tactical prototype except R/S support structure and ES.	A changed nozzle design, already effected, was used to preclude failure of graphite throat washers.
12	5-10-63 FP	RBs A and B did not extend, causing asymmetric trim condition. 1468 nm PX-2(D). All RBs instrumented.	RB extension linkage was modified.

A3X FLIGHT TEST SUMMARY (Continued)

Missile Number	Date/ Site	Major Anomaly	Corrective Action
15	5-17-63 FP	RBs B and C did not separate on command, probably defective FLSC. RB A OK. 1600 nm.	Shifted to another flexible linear shape change (FLSC) lot. Firing unit output cable given improved insulation and support.
25	6-6-63 EAG	None. Excellent flight 1598 nm. (High separation transient.)	None.
24	6-17-63 EAG	None. Excellent flight 1873 nm. (Dump computer did not issue commands because of noisy Waugh flowmeter.)	None.
22	6-21-63 FP	None. Excellent flight 1871 nm. (Dump commands intermittent, noisy Waugh flowmeter.)	None.
26	7-3-63 FP	None. Excellent flight 1891 nm.	None.
27	7-18-63 FP	None. RB did not tilt out (not considered major anomaly) but separated and landed 5 nm left. 1597 nm. First full tactical prototype except Project CLIP. First PX-2(P) lot. Carried for first time standard firing unit (with 2-pin connector).	Detailed inspection of tilt out mechanism. Next flight added instrumentation. New latch mechanism on A3X-38 and up.
33	7-26-33 FP	RBs separated late but not on command, firing unit malfunctioned, originating in PX (arcing of non-standard firing unit). Also heatshield failure. 1360 nm. First medium-range flight. PX-2(P).	RB firing unit circuitry isolated from PX. Special tests on heat shield and additional instrumentation.
36	8-13-63 FP	RB C (DW) separated several sec late, probably FLSC malfunction. Eject rocket probably fired. RB C landed 15 nm short, A&B close to target. 1299 nm. PX-2(P).	Increased FLSC heat protection, starting with A3X-38 (additional cork in RB separation joint area).
37	8-19-63 FP	NF did not separate, probably short in arm control circuit. No RB separation. 1970 nm. PX-2(P).	Cause not pinned down but CLIP changes helped improve the general situation.
38	8-30-63 FP	RB B separated properly, RBs A and C failed to separate, probably FLSC malfunction. 1599 nm. First PX-2(F) kit. Carried for first time an EBW coaxial connector in standard firing unit.	Modified the RB separation ring. Shifted from 7 grain FLSC to 9 grain MDF. Added shield to protect adjacent RBs.
39	9-26-63 EAG	None. Excellent flight. 1586 nm. (no down range data). First steam/gas eject launch. First 9 grain MDF and Mod separation ring. Complete PX-2.	None.
41	10-4-63 EAG	None. Excellent. 1586 nm. Tactical prototype. First full CLIP changes. PX-2.	None.
43	10-26-63 SSBN 619	None. Excellent flight. 2056 nm (High eject pressure. Missile exceeded maximum DB acceleration of 6 g's.) First SSBN launch.	None.
42	11-11-63 SSBN 619	None. Excellent flight. 2058 nm. (However, nozzle No. 3 stalled from 15.2 to 24.4 sec. High eject pressure — missile exceeded maximum DB acceleration of 6 g's.)	None.
44	11-27-63 EAG	Multiple electrical failure, beginning 45.4 sec, probably faulty connector. Destructed 54.9 sec. First PY-2 kit. PX-2	Cause of failure not pinned down. No corrective action for next few flights.
48	12-9-63 FP	None. Excellent flight. 1303 nm. (However, no PY signal received. Only 7 of 12 PX events monitored.) PX-2. PY-2.	None.

A3X FLIGHT TEST SUMMARY (Continued)

Missile Number	Date/ Site	Major Anomaly	Corrective Action
46	12-11-63 EAG	Nozzle No. 1 stuck at 21.4 sec at 8.5°F, control lost at 25.5 sec. Destructed 54.3 sec. (Multiple select failures at 27 sec much like A3X-44.) PX-2. PY-2.	None. However, this nozzle failure generated an extensive program of investigation at AGC and MSD.
50	1-7-64 FP	None. Excellent flight, 1303 nm. (However, PX-2 events did not occur, also no STAS received on XH-21.) PX-2. PY-2.	Increased environmental protection.
57 (A3Y-1)	1-20-64 EAG	RB A separated but eject rocket did not fire, resulting in collision with SS and falling short 37 nm. RBs B and C fell close to target. 2284 nm, maximum range shot.	The pullaway connection will be mated, and safety wired
58 (A3Y-2)	3-14-64 FP	SS nozzle No. 3 (Kaiser) lost throat at 82.7 sec. TVC tank ruptured 84.6 sec, chamber pressure lost 94 sec. NF separation and RBs A and B extended. Short-range shot.	Sweeping investigation instituted of Kaiser versus Valley Machine. Kaiser less dependable, for reasons not understood. Investigation continuing. Changing 1020 steel cone to 4130 steel is under consideration.
53	4-1-64 EAG PMR	None. Excellent flight. 1541 nm. PX events occurred and RBs separated Johnston Is. did not acquire and destruct attempted at 141 sec (after separation) and SS went out of control (after separation).	None.
55	4-8-64 EAG PMR	Missile did not stabilize in yaw, lost control at 21.1 sec, tumbled downrange, destructed 60.6 sec. Yaw attitude exceeded Missile Control Margin.	Guidance fix. Modification to 2 sticks (electronic modules) in the yaw steering logic.
60	5-12-64 EAG PMR	None. Excellent flight. 1542 nm. (However, no STAS on RB B due to shorting in velocity sensor input cable.)	An isolation resistor on future flights will isolate velocity sensor from vehicle electrical system. Also isolation resistors in STAS lines and in arm control lines will be added.
10	7-2-64 FP	None. Excellent flight. 1599 nm. Contained isolation resistors (adopted after A3X-60 flight) and STAS was received on all RBs.	None.

THE GOLDEN YEARS (1965 - EARLY 1971)

With the POLARIS A2P operational in June 1962 and the POLARIS A3X development flights commencing in August 1962, the Navy was well on its way to having a truly global Strategic FBM Weapon System. Moreover, the 2500 nm POLARIS A3 achieved operational capability, as scheduled, in the second half of 1964 (actually September 1964).

It was also during the time from 1962 - 1964 that strategic analysts postulated the Soviet defense would have an improved discrimination (radar) capability and a greater defense in depth with "SPRINT" type interceptors by the post-1967 period.

Various advanced POLARIS preliminary design concepts were studied by LMSC to offset the perceived Soviet threat. In October 1962, the POLARIS A3a was offered. It was a 66 in. diameter missile versus the prior 54 in. missiles. Concepts included a large single warhead, a three-warhead system, and penetration system options compatible with the missile system's desired maximum range.

This was followed by various POLARIS B3 missile concepts. Various reentry system configurations were evaluated (e.g., a single warhead, a cluster of multiple warheads, an aerodynamic maneuvering warhead, a low-altitude terminal dash). These configurations were code-named B3D, B3H, B3E, etc. Finally in July 1963, Lockheed proposed a POLARIS B3D to counter the expected (1969 to 1970) increased defense against ballistic missiles. The POLARIS missile diameter would increase to 74 in. The SSBN launcher's inner tube sized for a 54 in. diameter missile would be removed and non-launchable seals (pads) would be installed directly to the outer tube to accommodate the B3D's 74 in. diameter. The missile range would be in the order of 2000 nm and it would have a three-warhead system along with Pen-Aids (PX). Deployment of the warheads and PX would be from a platform with a cold gas (nitrogen) control system for reentry system altitude control. This was the beginning of what later became a "Bus" for reentry deployment/targeting. The system as proposed had hard target effectiveness plus improved penetration capability and versatility against defended urban/industrial targets.

During this same time frame, the Air Force generated (1962) a requirement for a new reentry vehicle which would become known as the Mk 12. Development of this new payload was authorized in late 1963 with the Director, Defense Research and Engineering proviso that it be a joint Navy-Air Force development. During March 1964, the General Electric Company, Reentry Systems Division, was authorized to develop it for Minuteman and POLARIS.

In May 1964, Lockheed proposed another POLARIS B3 configuration; a 74 in. diameter missile. This would double the volume and weight capability for a reentry system when compared to POLARIS A3. The reentry system would consist of six Mk 12 type warheads plus Pen-Aids. The range would be 2000 nm. At this time, anti-submarine warfare (ASW) projections and forward-based tender support did not warrant a further increase in missile range. Investigations of the performance potential, therefore, focused on increased payload flexibility and improved defense penetration.

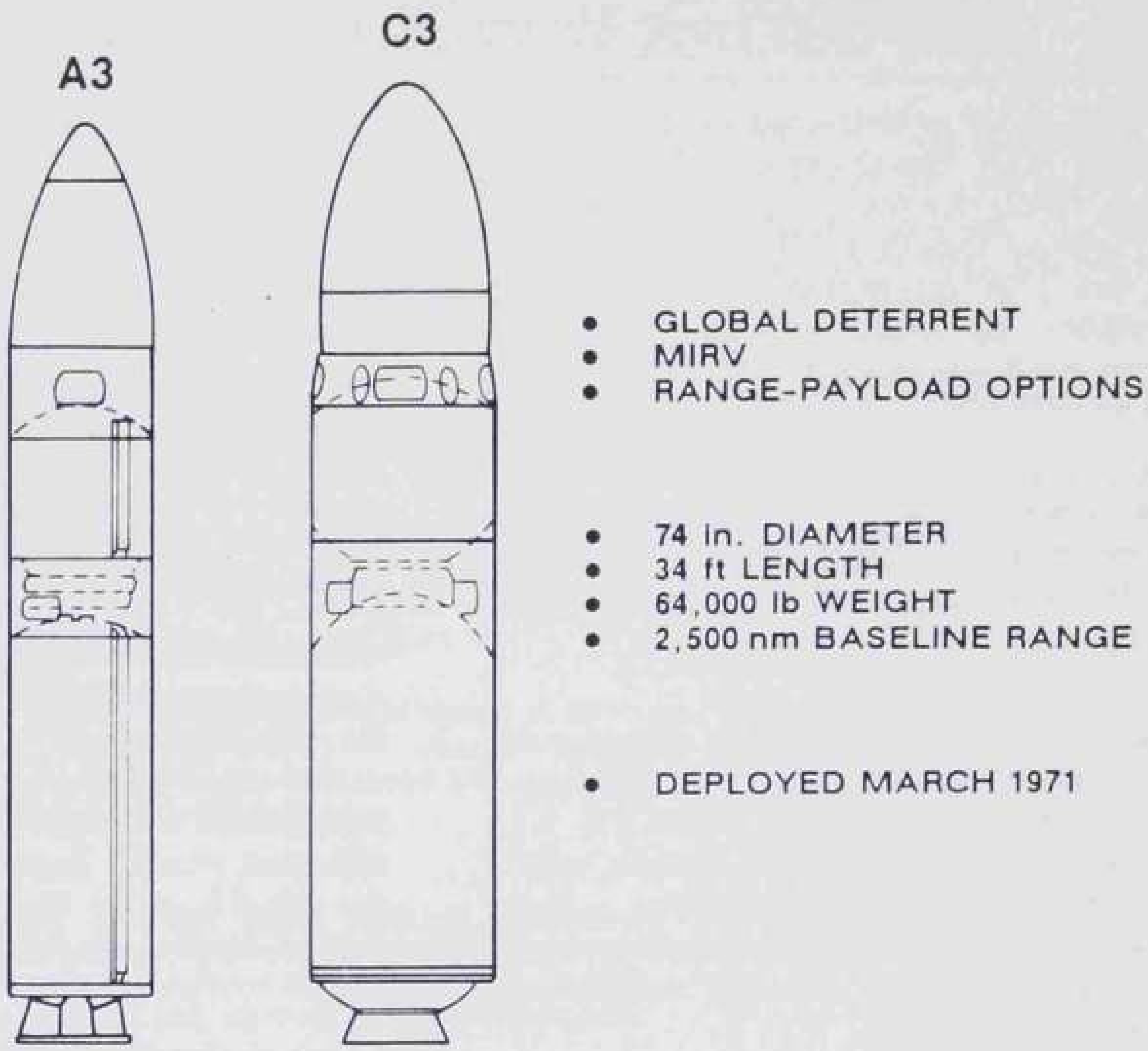
Guidance and controls were within the reentry system deployment platform with a warm gas reaction system for attitude control. The "Bus" had arrived — it was called the "Mailman" concept. There were other new design concepts for the B3 (e.g., FS and SS glass filament wound motor cases with thrust termination on the SS — six forward-facing thrust ports). Each motor had a single nozzle with fluid injection for TVC.

Later in October 1964, after conducting a B3 targeting study, Lockheed proposed a concept which extended the operation and flexibility of the "Mailman" concept by the use of modification kits for the deployment platform. The kits provided for changing six Mk 12's to four Mk 12's or twelve (new) small RBs and interchanging warm gas generators of the platform's attitude control system. This would vary the available energy source and provide single or multiple-targeting. This concept was "Flexi-flier."

Also during this 1964 time frame, Lockheed conducted a Large Ballistic Missile (LBM) study. With accuracy improvement forecasted for the Soviet ICBM system, the U.S. ICBM system's survivability came under question. Lockheed proposed a large two-stage, solid-propellant missile weighing approximately 602,000 lb with a range of 5,500 nm with multiple-reentry vehicles using advanced large payloads. The LBM would involve sea-basing, encapsulated in ocean depths down to 8000 ft. The Mk 17 RB, another Air Force–Navy potential development program, came under consideration. However, this RB concept became short–lived.

The Navy's role in the Strategic Weapon System world was assigned to the urban/industrial targets, and the LBM concept went away. The proposed POLARIS B3 with Mk 12 RBs was primarily identified as a single-target weapon. Incorporating a multiple-target capability, with a large number of smaller RBs (a new Navy Mk 3 RB) resulted in vastly improved cost-effectiveness (low cost per target). This led to a designation change, B3 to C3.

The multiple–target capability was achieved by the use of a number of smaller RBs and the "Flexi–flier"

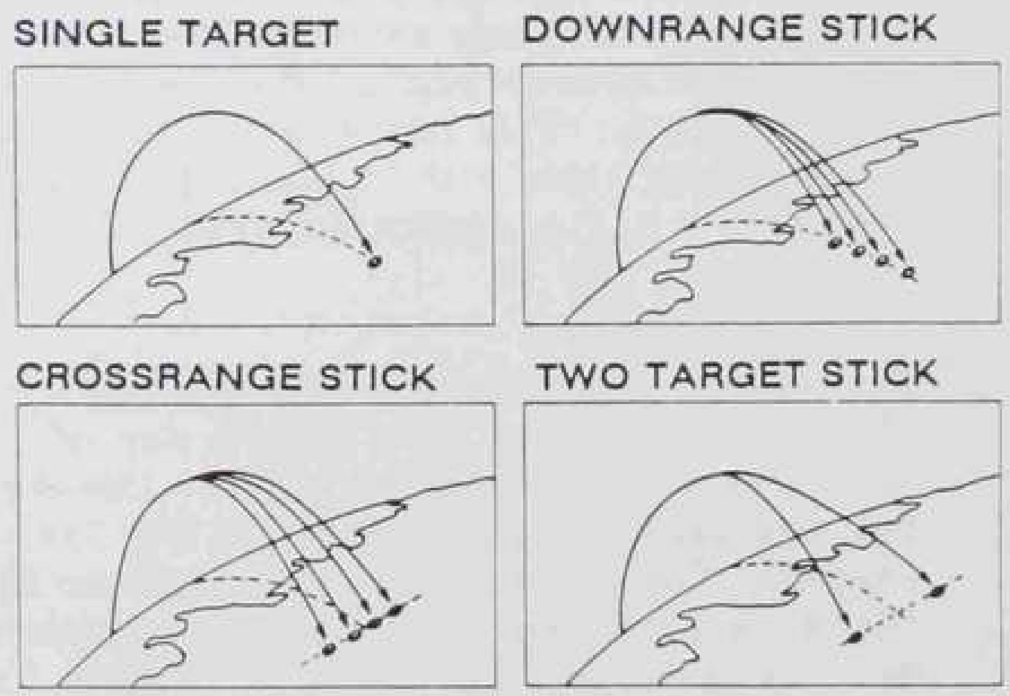


POSEIDON C3

concept (e.g., the equipment section acts as a "bus"). It has a gas generator, thruster valves and a control system which, after separating from the missile's booster system (rocket motors), provides an added velocity increment and maneuverability in space to position and separate RBs to separate independent targets. This Multiple Independently-targeted Reentry Vehicle (MIRV) capability provides the ability to deliver multiple RBs to a single target or to multiple targets. The impact of multiple RBs attacking more than one target from a single missile is described as the missile footprint. The RBs can be laid down in a downrange stick, a crossrange stick, or a combination of both. A single target attack with multiple RBs from a single missile poses a special design consideration. To prevent multiple RB kill by a single interceptor, the RBs must be spaced along the trajectory so that the distance between any two RBs at intercept altitude is greater than the (statistical) lethal diameter of the interceptor. Interceptor lethal diameter is determined primarily by the RB hardness and the assumed conservative interceptor warhead yield.

On 18 January 1965, President Lyndon B. Johnson announced in a special message to the Congress that his administration proposed to develop a new missile for the FBM System — POSEIDON. The POSEIDON C3 was to be 74 in. in diameter as compared to the 54 in. POLARIS. It was to be 3 ft longer than the 31 ft A3 and approximately 30,000 lb heavier. Despite this increase in size, the growth potential of the ballistic missile submarine launching system was to enable POSEIDON to fit into the same 16 launch tubes that carried POLARIS; modifications to the launch tubes and a new fire control system for the more complex MIRV targeting problem were to be required. POSEIDON was to carry twice the payload of the POLARIS A3 with significantly-improved accuracy.

The 64,000 lb POSEIDON C3 could carry up to 14 of the small Mk 3 RBs. These could be targeted bodies and could be targeted independently in the MIRV mode. Trajectory loft options were available, and the range could be extended by off-loading portions of the payload. The Post Boost Control System (PBCS), colloquially known as the "Bus," gave a large attack



MIRV Capability

The increased accuracy and flexibility of the weapon system would permit its use against a broader spectrum of possible targets and give added insurance of penetration of enemy defenses. As envisioned at that time, POSEIDON was to increase the system and force effectiveness of the FBM System by a factor of eight. This revolutionary multiple target per missile concept changed the course of national policy, strategic force structures, targeting doctrines, and operational planning. It also altered the quantitative and qualitative strategic balance.

On 16 February 1965, shortly after President Johnson's POSEIDON announcement, RADM Levering Smith relieved RADM Ignatius J. Galatin as Director, SPO.

Apart from the much-increased size and weight, the main difference between the POLARIS A3 and the POSEIDON C3 was the latter's capability of delivering RBs to single or multiple targets. Thus the principal area of development involved flight of the ES with the guidance system and RBs after they had separated from the booster. The ES's solid-propellant gas generator and associated steering capability allowed the guidance system to maneuver the ES and to eject RBs into ballistic trajectories to individual aim points.

Development of propulsion for C3 was undertaken by a joint venture of Hercules, Inc., and Thiokol Chemical Corporation. Both stages now had fiberglass cases. The FS used a composite propellant and the SS propellant was a double base. The C3 rocket motors were the first in the FBM program to feature single movable nozzles actuated by a gas generator and by hydraulic power units.

Other work centered on the development of an advanced all-inertial guidance system. Initial evaluations of a stellar-inertial guidance system were conducted in early 1966. Advanced development of a Mk 4 stellar-inertial guidance system was started in 1968. This effort was of an essential element of a new operational capability which became fully matured in the TRIDENT I and II.

Lockheed entered a 1 year Concept Design Phase (CDP) from February 1965 to February 1966. In March 1966, full-scale engineering development (FSED) began. However it was not until 12 March 1968 that a contract was executed. The Navy awarded Lockheed Missiles & Space Company, Inc. (LMSC) a $456.1 million cost-plus-incentive fee contract for development and production of the POSEIDON missile system. The contract represents one of the first awards made by the Navy Department providing for total operational system development and production (OSDP).

The contract called for 25 development (C3X) type flights to be followed by 5 Production Evaluation Missile (PEM) flights from an SSBN. The first C3X was launched from a flatpad at Cape Kennedy on 16 August 1968 several hours before the first Minuteman III launch. In view of the initial success of the development flights, the test plan was modified to 20 development flights versus 25. The PEMs remained at 5. Of these 20 flights, 13 were complete successes and 7 were failures. The last C3X flight was on 29 June 1970. This was followed on 17 July 1970 by the first submerged launch of a POSEIDON PEM successfully conducted from the USS James Madison (SSBN-627). The firing was observed by a Russian ship, LAPTEV, whose crew was unsuccessful in attempts to recover closure plate segments from the water after launch of the missile.

The remaining 4 PEMs were also successfully launched from the SSBN-627.

Finally on 31 March 1971, the USS James Madison (SSBN-627) deployed from Charleston, South Carolina, for operational patrol with 16 tactical POSEIDON C3 missiles. Deployment of the USS James Madison (SSBN-627) introduced the POSEIDON missile into the nation's arsenal of operational deterrent weapons and brought to successful fruition the development program announced in January 1965 for a successor weapon system to POLARIS. POSEIDON incorporated substantial improvements in accuracy and resistance to countermeasures over previous generations of missiles, but its principal advantage was in its flexibility, which provided a capacity for delivery for multiple warheads, widely spaced, on separate targets over a variety of target footprints.

All 41 SSBNs had been deployed by 3 October 1967. The first five SSBNs, USS George Washington class (SSBN-598), were deployed with POLARIS A1's. The next five SSBNs, USS Ethan Allen class (SSBN-608) were deployed with POLARIS A2's. Also, the next 9 boats of the USS Lafayette class (SSBN 616-626) were also deployed with POLARIS A2's. Plans called for the last 31 of the 41 SSBNs to all eventually carry POSEIDON C3 missiles. The 10 George Washington and Ethan Allen class SSBNs were to off-load their A1's and A2's and eventually have POLARIS A3 missiles plus be deployed in the Pacific. They operated out of Guam, serviced by the tender USS Proteus (AS-19) and, after 1967, by the tender USS Hunley (AS-31). The POSEIDON C3 missiles would all be deployed in the Atlantic, operating from tenders at Holy Loch, Scotland; Rota, Spain; and the new anchorage site established at Charleston, South Carolina. It was on 28 July 1965 that the USS Simon Lake (AS-33) officially became the support tender for Submarine Squadron Eighteen at an interim FBM anchorage at the U.S. Naval Station at Charleston, South Carolina. The anchorage was moved on 22 October 1965 to a permanent site on the Cooper River, Charleston, South Carolina.

OTHER GOINGS-ON DURING THE GOLDEN YEARS

Just as should be with any family, as it expands, equal attention has to be extended to all members of the family as they move through the years and not solely to the "newest." So it is with the FBM family: A1, A2, A3, and the new C3.

The POLARIS A1 Story Ends. On 2 June 1964, the USS George Washington (SSBN-598) returned to Charleston, South Carolina, to off-load missiles in preparation for overhaul at General Dynamics, Electric Boat Division, shipyard in Groton, Connecticut. This ended the initial deployment of the first FBM submarine, with POLARIS A1's which began in November 1960.

Finally on 14 October 1965, the USS Abraham Lincoln (SSBN-602) returned to the U.S., completing her initial deployment. She was the last of the first five SSBNs carrying the POLARIS A1 to return to the U.S. for overhaul. This marked the official retirement of the POLARIS A1 missile from active fleet duty. These first five boats were being refitted to carry POLARIS A3 missiles.

Adieu to A2. The USS James Monroe (SSBN-622) on 9 January 1968 became the first submarine with POLARIS A2's to enter overhaul and to receive POLARIS A3 capability. The USS John Marshall (SSBN-611) became the last submarine to give up her POLARIS A2's for POLARIS A3 capability when she went into overhaul on 1 November 1974.

POLARIS A3 Blue Ribbon. The POLARIS (A3) Operational Test (OT) program which began in September 1965 had effectiveness results which were significantly different than those of the A3 DASO. The POLARIS A3 OT program was suspended in January 1966 and on 17 March 1966, RADM Levering Smith (Director, SPO) convened a special A3 Blue Ribbon Committee to investigate. The co-chairman of the Blue Ribbon Committee were Dick Barse, SPO's Missile Branch Engineer (SP-2701) and Nick Chase, Lockheed/MSD's Director of Test Engineering (85-01). The Blue Ribbon Committee findings and recommendations were provided to RADM Smith during 29 August to 2 September 1966. Preparations to implement the recommendations were conducted between September and December 1966. The POLARIS A3 Blue Ribbon Phase II Recertification (corrective action implementation) program began at POMFLANT, Charleston, South Carolina, on all delivered/deployed A3 missiles in February 1967 and was completed prior to the start of the POLARIS A3T conversion program (October 1968). The POLARIS A3 OT program resumed in November 1967 with greatly improved results. The corrective actions implemented were:

1. Improved procedures for conversion of A3 missiles to the OT configuration.
2. Continuous monitoring during testing.
3. Cable improvements — routing of cables, vibration tests, improved inspection including x-ray.
4. ATJ motor nozzle replaced.
5. Fuzing, arming, and firing (FAF) cable cover SPALT.
6. Connector lock covers SPALT and pin retention tests.
7. Umbilical SPALT for connector corrosion.
8. Altitude testing of firing units.
9. Testing of guidance systems to remove degraded units.
10. Connector double mate.

PY-3 (Inflight Reliability Reporting). In the early years of the POLARIS program, a general requirement was postulated for a tactical inflight reliability reporting system. Such a system could be used to increase the bomb damage effectiveness of a fixed inventory of missiles.

Achieving the desired damage expectancy against enemy targets (with high confidence) often requires planning for multiple rounds with or without cross-targeting assignments. This is particularly applicable against high-value targets or for certain limited-strike options. Extremely high-reliability weapons could improve the confidence in achieving the damage expectancy goals. As an alternative...knowledge of the success or failure of certain missile system events could provide a basis for ordering additional, or withholding preplanned, missile launches to achieve the desired damage expectancy.

Concepts were investigated which would monitor critical missile payload events and transmit this information, via missile-borne equipment. Based on the success/failure information, the SSBNs could redirect missile launches. This was a "shoot-listen-shoot" scenario. This system would reduce the required inventory of missiles for the target base — or increase the bomb damage effectiveness for a fixed inventory of missiles.

This inflight reliability reporting system received the acronym "PY." In 1963, the PY-1 program conducted preliminary development of a transmitter/antenna system mounted on the door of the POLARIS A2 ES. The PY-1 program was limited to developing 30 units for test, including flying 11 of them on A2 DASOs (SSBNs 619, 622, 623, 624, 625) from October 1963 through April 1964.

SSPO directed continuous study of new PY concepts for tactical application. A completely new design for use on POLARIS A3 was identified as PY-3, with the preliminary development hardware, PY-2, being produced and flight tested on A3X-10, -13, -44, -46, -48, -50, -59 and -60 in 1963 through December 1964.

In March 1965, Lockheed was contracted to commence full-scale development of the tactical PY-3. This system again was mounted on the inner surface of the POLARIS A3 ES access door. Upon completion of a successful missile boost flight (deployment of POLARIS Mk 2 RBs), the transmitter/antenna was ejected and began transmitting indications of a successful flight.

Six PY-3 units were built in 1965 for engineering development testing. Twenty units were built for flight confidence testing (FCT), engineering evaluation testing (EET), phase proofing of production test consoles, and flight testing. These 20 units were built during 1966 and 4 were flown on POLARIS A3 DASOs in 1967. Tactical production began in late 1967 resulting in the delivery of 150 PY-3's in 1968.

Deployment of PY-3's into the fleet never came about. Due to the fact that the mode of operation called for the PY-3 unit broadcasting back to a SSBN "trailing" receiving equipment, the fleet command and SSBN skippers alleged that their location would be jeopardized. In addition, analysis showed effective information was not provided with possibly misleading data.

Radiation Evaluation and Design Study (READS). With improvments in the Soviet antiballistic missile system (Galosh interceptor) in early 1965, the potential for an exoatmospheric nuclear burst upsetting the POLARIS missile's electronic system had to be considered. Prior concern had been associated with reentry body but now the Transient Effect on Electronic Systems (TREES) during boost phase became a factor. An investigation of the POLARIS system's susceptibility to this phenomena was given the acronym READS. In addition to boost phase, "hardness" of the reentry system had to be considered plus reducing the defense system effectiveness by the use of Pen–Aids. Various concept design studies culminated in the POLARIS ANTELOPE program.

POLARIS ANTELOPE (A3T) Program. The ANTELOPE development program was undertaken to provide improvements in the POLARIS A3 missile, to increase its survivability in a nuclear environment. ANTELOPE was the name given to the combination of several other programs having the similar objective — survivability. For example:

CORAL — studies of radiation effects on missile electronics and a lofting flight trajetory

TOPSY — the start of POLARIS A3 missile redesign based on CORAL-type studies

MARK-UP — redesign of the Mk 2 RB to make it more radiation-resistant

EXO-PAC — a study and redesign to replace a Mk 2 RB with a Pen-Aid carrier

HEXO — combined program of MARK-UP and EXO-PAC

ANTELOPE — TOPSY (missile body) and HEXO (RB) combined into one program (October 1965)

IMPALA — the Pen-Aids to be used with HEXO incorporated into ANTELOPE (September 1966).

The ANTELOPE Program for improving the capacity of the A3 missile was approved in 1965, and the development effort began on 1 August of that year.

The first ANTELOPE development flight test vehicle was launched from a flat pad on 11 November 1966 for a partially-successful flight.

The ANTELOPE development program continued with nine flights during 1967, including five from the USS Observation Island.

Two special ANTELOPE DASO firings were conducted in 1968 from SSBN-626 after its return from deployment and prior to start of overhaul.

The ANTELOPE development program was completed in 1968 with four development flight tests, for a total of 14 flights. One flight test was cancelled.

The ANTELOPE missile was called POLARIS A3T, hardening of the missile body electronics against nuclear radiation. The Impala design Pen-Aids and carrier (modified Mk 2) was developed and named POLARIS A3A but it never went into production.

For additional information on ANTELOPE, Impala and other FBM Pen-Aid programs, see the PENETRATION AIDS PROGRAMS section of this document.

The delivery of A3T missile hardware began in mid-1968 with the assembly of the first missiles in time to permit outload of SSBN-626 in August for the special DASO exercise. Tactical outloading of A3T shipfill missiles began in October and, by the end of the year, SSBNs 636, 644, and 657 were redeployed with A3T missiles. All POLARIS A3Ps were replaced with A3Ts in the Atlantic by 17 July 1970 and in the Pacific by 26 March 1972.

The ANTELOPE missile body (A3TX) and reentry system (A3TY) development flight test program is provided in this document following the POSEIDON C3X development flight test program.

POSEIDON Supplemental Flight Test (SFT) Program. (The following text was extracted from Reference (2).) The SFT Program provided a means of flight testing the proposed POSEIDON (C3) RB, 2 years in advance of the POSEIDON missile on which it was destined ultimately to ride. When inaugurated by the Navy on 16 February 1966, the idea of flight testing the RB separately was regarded in many quarters as an expensive luxury. It is now known to have been a constructive, money-saving innovation, and a good example of the effective use of procedural innovation to produce savings.

In 1956 - 1958, the pacing elements in the development of a new missile system were propulsion and guidance — not the reentry system. As a result, the number of test flights was determined by missile needs as the reentry system required fewer flights and got a free ride on the missile flights.

In 1964 - 1965, it was recognized that, for the POSEIDON missile, the reentry system would require more flight testing than the missile because of: (1) significant increase in the severity and difficulty of the reentry mission, and (2) a reduction in risk in propulsion and guidance. The implication was a very expensive stretch out of the flight test program, and a probable delay in the Operational Availability.

The POSEIDON missile was to carry MIRVs. Thus, the POSEIDON reentry vehicles had to be small, have a low weight, and additionally have a high beta configuration (i.e., high ballistic coefficient) so as to minimize the time required for reentry. (NOTE: Shortening the reentry time reduces the defense acquisition time during reentry and considerably complicates defensive measures.) Further requirements were accuracy, which meant heavy emphasis on reentry vehicle separation dynamics and stability, and hardness to enemy countermeasures weapons. High Beta ALSO improves reentry accuracy.

Lockheed proposed to the Navy that advantage be taken of the newly-available Athena boosters to initiate a separate RB flight test program to provide early testing of the RB using the Green River/White Sands Missile Range. The predicted benefits were: (1) getting RB flight test data up to 2 years earlier than the first POSEIDON flight, (2) better reentry data due to the superior range facilities at the White Sands Missile Range, and (3) substantial cost saving, both from shortening the program and because an ATHENA flight costs substantially less than a POSEIDON flight. This proposal was accepted by the Navy and, on 16 February 1966, a Letter of Intent was issued for an eight-flight SFT Program. In June 1966, three more flights were added and, in 1967, yet two more for a total of thirteen flights.

Nine of these flights were successful, one was partially successful, and three were "no test" due to booster failures. The first flight was on 22 September 1966, only 7 months after "go-ahead" — a record both for the shortness of the time span and, more important, because it was the first successful flight of a high beta RB. Additional flights, following in rapid succession, made possible the orderly, evolutionary development of a high beta, heatsink body/low erosion nose RB. The thirteenth, and last, flight was on 12 December 1968.

The Lockheed effort was organized so as to maintain for the SFT Program the benefits of large company resources and yet provide the flexibility and speed of a small organization. This was done by assigning the entire engineering, manufacturing and testing responsibility to one engineering manager (specifically, the Division Manager of "Reentry Systems Engineering") so that he had complete control of the work, whether done within his own division or "subcontracted" out to other departments. As only a few departments were given "prime" responsibilities, coordination remained quick and easy — and decisions rapid — even though at least 50 departments contributed to the program. Throughout its life, the SFT Program had a top priority within Lockheed.

The RBs flown on the SFT received a heavy infusion of analysis into their early conceptual design, making them truly, in a sense, the first analytically designed RBs. This analytical approach generated sufficient confidence in the fundamental soundness of the design that, when materials of a size and configuration beyond the present SOTA were called for, the design was not changed. Instead, a materials and process development program was launched to provide the materials needed.

The materials program was outstandingly successful and provided materials of quality and size needed for the RB nose, heatshield, antenna windows, and jacket. Another area where design requirements exceeded the SOTA was in instrumentation, and here again the needs were met (e.g., high thermal response, minaturized telemetry links (VHF 2UHF) with solid-state commutation and a delay link).

The flight test schedule was a prime constraint on design. The first SFT was designed, built, tested, and flown in 7 months from program go-ahead — undoubtedly a record, as the norm is 18 to 24 months. Other flights followed in rapid succession. Both design and ground testing were sharply limited in the time available for their functions. The discipline that nothing be flown until it had been ground tested first was observed throughout the program.

STRAT-X and ULMS (Undersea Long Range Missile System)

It was during These Golden Years (1965 - early 1971) that a series of DoD studies called STRAT-X and ULMS were conducted, which would eventually be reflected in the FBM System in later years. These studies are briefly touched on here, but they resulted in TRIDENT. Hence they will be discussed in more detail under C4, "The Expanding Years" section.

On 1 November 1966, the SECDEF initiated a comprehensive study effort termed STRAT-X to examine future U.S. ballistic missile basing concepts and missile performance characteristics required to counter potential Soviet strategic offensive forces and anti-ballistic missile proliferation during the 1975 to 1985/90 time-frame.

The STRAT-X Study was performed by the Research and Engineering Support Division of Institute for Defense Analysis (IDA) in response to Advanced Research Projects Agency (ARPA), Contract DAHC15 67 C 0011, Task Order T-56. Many individuals, government agencies and industrial organizations furnished information which was used in the preparation of the STRAT-X reports, but the responsibility for the contents is taken by the individuals shown below.

Gen. Maxwell D. Taylor — President, IDA

Dr. Ali B. Cambel — Director, RESD Division of IDA

Dr. Robert H. Fox — Deputy Director, RESD Division of IDA

Mr. Fred A. Payne — Director, STRAT-X Study (Deputy Director - DDR&E)

Mr. Dewey Rinehart — Chairman, Design Panel

Mr. Clifford Cummings — Chairman, Reactions Panel

Dr. Irving Yabroff — Chairman, Evaluation Panel

The Design Panel studied various missiles system concepts (missile designs, penetration system designs, and basing concepts), both for the Air Force and Navy. The panel considered hard silos, tunnels, mobile missiles, defended fixed launch sites, shipbased, and undersea based, etc. The Evaluation Panel evaluated proposed candidate systems, and the Reaction Panel "functioned" as the Soviet government in studying the outputs of the Design Panel. Dr. Willy Fiedler of Lockheed was connected with the undersea basing in support of the SPO. His study area was ULMS. The STRAT-X Study began in November 1966 with briefings of the study findings to various DoD levels in the month of July 1967.

The resulting ULMS Study was a new submarine concept based in the continental U.S. (CONUS), with more than 16 missiles (probably 24) and deeper cruising depth. The missile would be new, with increased throwweight and range and possibly encapsulated to accommodate a deeper launch.

Upon completion of the DoD's STRAT-X Study, the Navy (SPO) continued its own studies of advanced undersea system concepts. Lockheed, General Electric, MIT, Sperry, and Westinghouse were all involved. Electric Boat, was funded by Navships for interfacing submarine studies. The SPO was redesignated Strategic Systems Projects Office (SSPO) on 29 July 1968. The ULMS program was established by the CNO on 4 October 1969. The ULMS Project Manager (PM-2) was established under the Chief of Naval Material (CNM) on 31 March 1971. He was responsible for the entire ULMS under the CNM. The SSPO as PM-1 was responsible for the strategic missile system (e.g., missile, fire control, guidance, launcher, navigation). NAVSEA was responsible for the ULMS submarine per se. Each of them submitted their resource requirements, etc. to PM-2 as the inputting coordinator for the CNM.

Interservice Signature Experiments Program (ISEP)

To gather RB survivability data in a hostile environment, the ISEP Program was conducted in conjunction with the Air Force during the 1967 to 1968 timeframe.

The ISEP was a series of RB signature experiment programs directed toward:

1. Identifying individual characteristics which collectively form an overall signature for a reentry vehicle.
2. Determining the threshold velocities at which RB wake becomes the primary means of discrimination.
3. Developing discrimination means for bodies reentering at velocities below the wake threshold.

Six flight tests were conducted for the program during 1967 and 1968. The payload for each of the six tests consisted of a modified instrumented Mk 2 RB.

Each flight was conducted into the Kwajalein test area using a modified fleet-retired A1 missile with a Mk 1 guidance system.

Missile launches for each of the six flight tests were made from the USS Observation Island (EAG-154).

The Pacific Missile Range test facility provided calibrated telemetry, radar, and infrared/optical receiving systems including applicable recording devices to measure and record missile and reentry system performance data.

The baseline ISEP test missile system configuration consisted of a refurbished fleet-retired A1P missile, modified ES, extension section, and transition section capable of mounting either a Mk 2 or Mk 12 RB.

The function of the transition section was to provide RB orientation and spin-up, and to reduce nutation effects to a minimum prior to RB separation from the transition section.

The transition section attached to the extension section and provided attachment hardware at its forward end for attachment of a Mk 2 or Mk 12 reentry vehicle.

The extension section provided space between the transition section and the ES to contain the reentry system ejection rocket motors, the attitude control system control nozzle clusters, and the Freon tank.

The transition section provided space for mounting the payload attitude control system, power sources, portions of the reentry system electrical and instrumentation systems including cabling and connectors, payload rocket motors, and separation devices.

The payload attitude control system reoriented and spun up the reentry system and, after RB separation, de-spun the transition section. The transition section, upon completion of de-spin, had the retro rockets move the transition section to a new reentry path.

The Navy had missile body performance data reduction, but the reentry data was the responsibility of the downrange (Kwajalein) facility — Air Force.

Safeguard Systems Test Target Program (SSTTP)

Following the signature experiments of the Air Force (ISEP) using POLARIS Al's, an antiballistic missile target test program using POLARIS A2's and A3's was conducted (SSTTP). Evolution of the program took place over a nine-year period beginning in 1963 when the use of POLARIS boosters for antiballistic missile targets was first proposed by LMSC. Concurrently, the USAF was assigned the mission of providing antiballistic missile targets. However, since sufficient joint-use targets were not available, efforts were initiated in July 1966 for a study of candidate vehicles. LMSC provided target vehicle design concepts in support of that study during September 1966.

Recommendations resulting from the study were incorporated in the Nike-X Project Office (NXPO) five-year test plans which were presented to the DoD in December 1966. The use of POLARIS-derived target vehicles, along with USAF-provided vehicles, was recommended by NXPO. Concurrence of the DoD resulted in a January 1967 SECDEF memo to the US Navy and USAF directing their support of NXPO target program planning activities. Accordingly, LMSC, USN/SPO, and NXPO initiated program definition effort in February 1967, and contractual support of the LMSC planning activities was first issued in July 1967.

A Program Executive Plan called for program initiation in April 1968. The planned total number of POLARIS-derived target vehicles changed from 45 to 40 (previously as high as 65) with a first flight in November 1969. In May 1968, the first flight was rescheduled to February 1970 and POMFPAC was to be the missile assembly facility for test in the Pacific. There were three basic missile configurations: A2 with PX-1 Pen-Aids and a Mk 2 reentry body (5 each); A2 and Auxiliary Payload Extension (APEX) and a Mk 2 reentry body (12 each); and A3 with PX-2 Pen-Aids and Mk 2 reentry bodies (23 each). APEX was a cylindrical extension between the missile equipment section and the reentry body, with AF targets enclosed. There were also AF Radar Augmentation Devices (RADs) balloons tethered from the aft flare of some of the reentry bodies.

Subsequently, several program changes occurred. The first flight was rescheduled to May 1970, then to August 1970, then to March 1971 with the first flight actually taking place on 15 April 1971. Advanced Ballistic Missile Defense Agency (ABMDA) test objectives were also incorporated into SSTTP by the addition of 15 in. sphere auxiliary payloads to the A2/APEX/Mk 2 missile configuration (to be ejected from the APEX cylinder). The assembly facility was shifted from POMFPAC to POMFLANT and then finally to ETR. POMFLANT provided missile hardware logistics and package checkout. ETR performed the final assembly and checkout. The missiles were airlifted to an advanced base in the Pacific and loaded on the launch ship, EAG-154 Observation Island.

Specific objectives were asigned for each mission based on the target requirements established by Bell

Telephone Labs (BTL) and Safeguard Systems Command (SAFSCOM). In support of these objectives, LMSC, assisted by the Navy, effected the following:

- Launched four A2/APEX/Mk 2 missiles and one A3/Mk 2 missile equipped with Teflon and Nylon Phenolic reentry bodies and RADs, where required, to designated target intercept points.
- On three of the A2/APEX/Mk 2 Flights, 15 in. copper spheres provided by the ABMDA were launched on specified trajectories.

The launch area was approximately 700 miles northwest of Midway Island with Kwajalein Atoll the target area. The USNS Wheeling provided telemetry/radar and range safety support. Five flights were made during 1971 beginning with Mission M1–7 on 15 April (A2S–01). Mission M1–8 (A2S–03) on 6 May, Mission M2–5 (A2S–02) on 10 November, Mission M2–8 (A2S–04) on 13 November, and Mission M2–3 (A3S–01) on 9 December followed as scheduled. Each A2/APEX/Mk 2 vehicle flown exhibited somewhat anomalous operation; however, essentially all planned SAFSCOM test objectives were satisfactorily accomplished and, as a result of these somewhat anomalous flights (reentry body did not tilt, causing lateral miss distance of several miles), additional nonscheduled safeguard objectives were achieved. The A3/Mk 2 vehicle (A3S–01) was completely nominal.

SAFSCOM planning revisions during early 1972, together with a flight schedule slippage made necessary by DoD diversion of the range support ship USNS Wheeling, resulted in a SAFSCOM decision to cancel all further requirements for POLARIS target vehicles. Accordingly, on 14 April 1972, SAFSCOM directed the USN/SSPO to terminate the POLARIS SSTTP and dispose of all residual assets. On 28 April 1972, SSPO notified LMSC to initiate termination of the SSTTP contract.

HIGHLIGHTS (1965 - EARLY 1971)

Some of the following highlights were extracted from SSPO's document "FBM Facts/Chronology — POLARIS, POSEIDON, Trident" dated 1982 (reference 5), and Fleet Ballistic Missile System Program History, Volume 1, dated 31 December 1986, by Lockheed.

18 Jan 1965 — President Johnson announced in a special message to the Congress that his administration proposed to develop a new missile for the FBM System. "POSEIDON (C-3) will be 100% different from the POLARIS A-3. It will be 6 feet in diameter, as opposed to the 4 1/2-foot POLARIS. It will be 3 feet longer than the 31-foot A-3. Yet despite this increase in size, the growth potential of the ballistic missile submarine launching system will enable POSEIDON to fit into the same 16 missile tubes that carry POLARIS. Only a minor and relatively inexpensive modification to the missile tubes will be required. POSEIDON will have double the payload of the POLARIS A-3 and will be twice as accurate. Like POLARIS A-3, it will be able to reach any spot on earth from its nuclear-powered nesting place."

16 Feb 1965 — RADM Levering Smith relieved RADM Ignatius J. "Pete" Galatin as Director, SPO.

28 Jul 1965 — An interim FBM anchorage site was established at the U.S. Naval Station, Charleston, South Carolina, with the USS Simon Lake (AS-33) as the FBM tender. The USS Simon Lake (AS-33) officially became the support tender for Submarine Squadron Eighteen.

14 Oct 1965 — The USS Abraham Lincoln (SSBN-602) returned to the U.S., completing her initial deployment. She was the last of the first five SSBNs carrying the POLARIS A1 to return to the U.S. for overhaul. This marked the official retirement of the POLARIS A1 missile from active fleet duty.

22 Oct 1965 — The Cooper River FBM anchorage site near Charleston, South Carolina, became operational when the USS Simon Lake (AS-33) moved from the interim site to this location.

31 Dec 1965 — By the end of the year, the buildup of A3 capability continued; 24 submarines were deployed by the end of the year (including 11 with A3 missiles — four were in the Pacific operating from the tender based on Guam).

2 Feb 1966 — The USS George Washington (SSBN-598), the first submarine ever to carry POLARIS missiles on operational patrol, completed her initial overhaul. She was refitted to carry the 2500 nm range POLARIS A3 missile, and departed Charleston, South Carolina, for operational patrol with 16 POLARIS A3 missiles on 30 June 1966.

17 Mar 1966 — RADM Smith (SP-00) convened a special A3 Blue Ribbon Committee to evaluate the difference between POLARIS A3 DASO performances and that of the POLARIS A3 OT Program. A3 OT operations had been suspended in January 1966. The Blue Ribbon Committee findings resulted in corrective actions at POMFLANT to all A3 missiles commencing in February 1967 and renewal of OT operations in November 1967.

26 Jun 1966 — The USS Canopus (AS-34), last of five planned FBM tenders, was deployed to the Cooper River anchorage to relieve the USS Hunley (AS-33).

1 Nov 1966 — The SECDEF initiated a comprehensive study effort termed STRAT-X to examine future ballistic missile basing concepts and missile performance characteristics required to counter potential Soviet strategic offensive forces and anti-ballistic missile proliferation.

17 Nov 1966 — The first in a series of ANTELOPE (A3) development missiles was successfully fired from a launch pad at Cape Kennedy, Florida.

31 Dec 1966 — By the end of the year, the first three of the 598-class submarines to

be converted to A3 capability were overhauled and redeployed with A3 missiles. Additionally, 8 new 627-class submarines were deployed with A3 missiles. These additions plus the 11 deployed in 1965 made a total of 22 submarines with A3 missiles. The A2 FOT program also continued throughout 1966. Overhaul started on four of the 608-class submarines, thus reducing the number of A2 submarines deployed at year-end to 9. Full-scale engineering development of the POSEIDON C3 missile system, with substantially increased capability over the POLARIS series, was begun in March 1966.

7 Apr 1967 — First STV-4K POSEIDON (C3) special test vehicle was launched from PEASHOOTER and caught by a special crane (Skycatch).

3 Jun 1967 — The USS Abraham Lincoln (SSBN-602), last of the five SSBNs that carried POLARIS A1, completed her conversion to carry A3.

Aug 1967 — STRAT-X Study Report promulgated.

3 Oct 1967 — The USS Will Rogers (SSBN-659), last of the 41 authorized SSBNs, departed Charleston, South Carolina, for operational patrol with 16 POLARIS A3 missiles.

31 Dec 1967 — By the end of the year, 13 A2 FOT firings, 3 A3 OT, and 5 A3 DASO firings had taken place during 1967. The ANTELOPE development program continued with nine flights during the year, including five from the USS Observation Island (EAG-154).

POSEIDON C3 development also continued in 1967. Significant events included: (1) the completion of the first series of STV-4K PEASHOOTER launches, (2) the full-scale static firings of FS and SS motors, and (3) the FS combined system tests of FS motor and TVC.

1 Feb 1968 — Advanced development objectives for a ULMS was established by the CNO.

15 Feb 1968 — HMS resolution (SSBN-01), the Royal Navy's first nuclear-powered submarine to be outfitted with the POLARIS weapon system under the terms of the POLARIS Sales Agreement, successfully launched a POLARIS A3 missile down the Atlantic Missile Test Range while cruising submerged off Cape Kennedy. (On 4 March, the Starboard Crew successfully launched a POLARIS A3.)

12 Mar 1968 — The Navy awarded LMSC a $456.1 million cost-plus-incentive fee contract for development and production of the POSEIDON missile system. The contract represented one of the first awards made by the Navy Department providing for total Operational System Development and Production (OSDP).

28 Jun 1968 — The last production-line A3 missile was turned over to the Navy by Lockheed, prime contractor.

29 Jul 1968 — The SPO was officially redesignated the SSPO to reflect additional responsibilities assigned by the CNO for strategic offensive and defensive systems.

16 Aug 1968 — The first test flight model of the POSEIDON missile (C3X-1) was successfully launched from a launch pad at Cape Kennedy. Principal objective of the test was basic missile development. The POSEIDON was scheduled for deployment on 31 of the 41 FBM submarines.

20 Nov 1968 — The USS Francis Scott Key (SSBN-657) returned to Charleston, South Carolina, and thus marked the successful completion of the 600th deterrent patrol by units of the POLARIS submarine force, and the equivalent completion of the POLARIS submarine patrolling completely submerged for 100 years. Since the initial patrol (in November 1960), 36,500 days of patrol vigilance have been successfully completed.

31 Dec 1968 — By the end of the year, overhaul of the USS Proteus (AS-19) was completed, and the ship resumed support of the Pacific submarine fleet. The USS Hurley (AS-31) returned from Guam and assumed tender support at the Cooper River site.

Overhaul of the USS Holland (AS-32) was started, and overhaul and conversion of the USS Observation Island (EAG-154) to C3 capability began.

The ANTELOPE A3T development program was completed with four development flight tests, for a total of 14 flights. One flight test was cancelled.

The delivery of A3T missile hardware began in mid-1968 with the assembly of the first missiles in time to permit outload of SSBN-626 in August for the special DASO exercise. Tactical outloading of A3T shipfill missiles began in October and, by the end of the year, SSBNs 636, 644, and 657 were redeployed with A3T missiles.

5 Apr 1969 — The 100th POLARIS patrol in the Pacific was completed when the USS Stonewall Jackson (SSBN-634) returned to Apra Harbor, Guam.

4 Oct 1969 — The ULMS Program was established by the CNO.

17 Oct 1969 — SSPO was relocated to new quarters in Building No. 3, Crystal Mall, 1931 Jefferson Davis Highway, Arlington, Virginia.

16 Dec 1969 — The fourteenth flight test of POSEIDON was conducted from the surface missile test-firing ship, the USS Observation Island (EAG-154). This was the first operational missile tube launch and the first complete test of the POSEIDON weapons system, including the launcher, fire control, and missile subsystems.

24 Dec 1969 — After the first overhaul, the USS Nathan Hale (SSBN-623) deployment began in the Pacific with A3 missiles. The SSBN-623 was the first of six SSBN-616 class transferred to the Pacific.

26 Mar 1970 — ULMS Program Steering and Working Groups were established. The groups were established to provide program guidance, a forum for program problems, and periodic evaluation of program progress. The groups were established to derive a list of key events, solve problems, monitor progress, and ensure continuous and effective communication.

29 Jun 1970 — Twentieth POSEIDON test missile was launched from Cape Kennedy.

17 Jul 1970 — An exchange program to replace all POLARIS A3P missiles in the Atlantic Fleet with POLARIS A3T missiles was completed.

3 Aug 1970 — The first submerged launch of a POSEIDON PEM successfully conducted from the USS James Madison (SSBN-627). The firing was observed by a Russian ship, LAPTEV, whose crew was unsuccessful in attempts to recover launcher closure plate segments from the water after launch of the missile.

21 Sep 1970 — The POSEIDON development flight test program was concluded.

31 Dec 1970 — By the end of the year, the C3 Development Flight Test Program was completed. The year 1970 also saw the start of C3 production missile and RB deliveries, completion of conversion of the first four SSBN-627 class SSBNs to C3 missile capability, and the underwater launch of C3 PEM and DASO missiles from SSBNs 627 and 629. To support C3 missile deployment, the USS Canopus (AS-34) and TAK-282 completed conversion.

The last of SSBN-616 class A2 SSBNs to be converted to A3 (625) was deployed in the Pacific, thereby completing replacement of the SSBN-627 class SSBNs which were formerly deployed in the Pacific and now either are converted or are undergoing conversion to the C3 missile capability.

31 Mar 1971 — The USS James Madison (SSBN-627) deployed from Charleston, South Carolina, for operational patrol with 16 tactical POSEIDON C3 missiles. The USS James Madison's deployment introduced the POSEIDON missile into the nation's arsenal of operational deterrent weapons and brought to successful fruition the development

program announced in January 1965 for successor weapon system to POLARIS.

31 Mar 1971 — The ULMS Project Manager (PM-2) was established under the CNM.

HIGHLIGHTS U.K. PROGRAM

Dec 1962 — Meeting with Prime Minister Macmillan and President Kennedy; decision made to use the POLARIS missile in British submarine fleet.

Jan 1963 — Decision that Britain would build total of 4 FBM submarines. British technical missions in U.S. for detailed study of American FBM system.

6 Apr 1963 — POLARIS sales agreement signed, followed by prompt implementation of its terms.

Jun 1966 — Total of 250 U.K. personnel already trained on submarines, checkout, electrical, and mechanical equipment. Contracts released to U.K. industry for manufacture of various parts of their weapon system.

30 Jun 1966 — Royal Navy POLARIS Weapon System School was commissioned at Armament Depot, Coulport, Scotland.

Sep 1966 — HMS Resolution (SSBN-01), launched from shipyard in north of England as first of British-designed submarines using POLARIS missile system.

Feb 1967 — HMS Renown (SSBN-02), launched from a British shipyard as second U.K. submarine using POLARIS missile system.

Nov 1967 — HMS Repulse (SSBN-03), launched as the third British-designed submarine using POLARIS missile system.

15 Feb 1968 — HMS Resolution (SSBN-01), launched A3E/UK-670 on 1275 nm flight into the Antigua MILS target area. This was first test of a series of U.K. DASO tests to be conducted during 1968 – 1969 on Eastern Test Range from U.K. SSBNs. Initial test was successful.

Mar 1968 — HMS Revenge (SSBN-04), launched as the fourth POLARIS-equipped submarine of the British strategic nuclear deterrent force, making a total of four such boats which would operate from Scotland.

4 Mar 1968 — HMS Resolution (SSBN-01), launched A3E/UK-666 on 1275 nm flight into the Antigua MILS target area. Test was entirely successful.

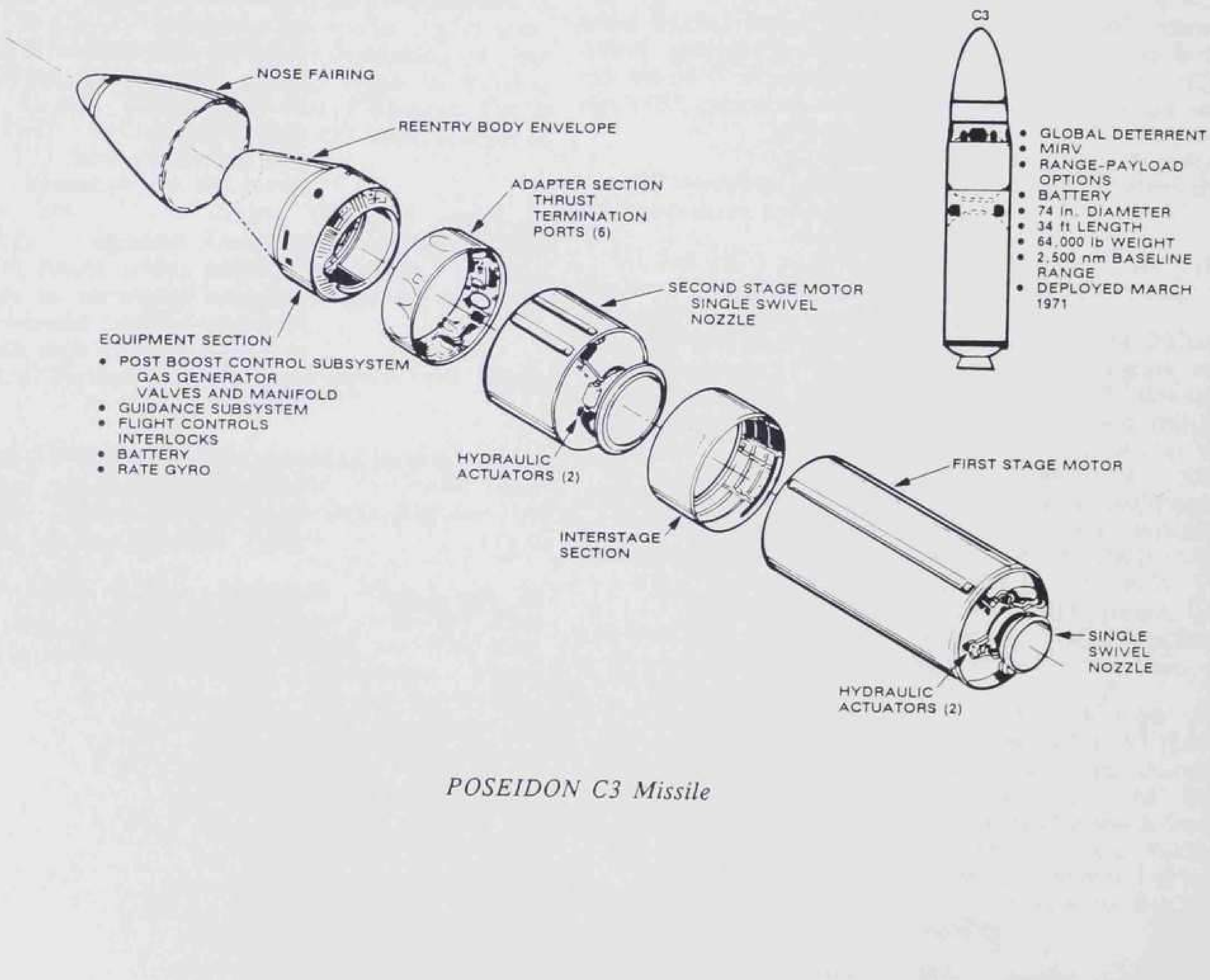
Jun 1968 — HMS Resolution (SSBN-01) began its first operational patrol, carrying 16 POLARIS A3P missiles.

C3X FLIGHT TEST SUMMARY (1968 - 1970)

C3X General Characteristics

Two-stage solid propellant with a length of 34.1 ft, 74 in. diameter with a range of approximately 2500 nm, weight of approximately 65,000 lb. The ES (forward of the SS) is 72 in. in diameter which separates from the booster. It is equipped with the missile all inertial guidance system, a solid-propellant gas generator PBCS and RBs. This provides maneuvering of the ES and ejection of RBs into ballistics trajectories to individual targets, MIRVs.

Both rocket motors have fiberglass cases, with single movable nozzles. The SS motor has six thrust termination ports (thrusting forward) which are activated at ES separation. Multiple individual-targeted small RBs (Mk 3) were developed as the POSEIDON payload.



POSEIDON C3 Missile

POSEIDON (C3X) FLIGHT TEST SUMMARY

Missile Number	Date/ Site	Success/ Failure	Problem/Anomaly
C3XD-01	8-16-68	Success	(1) AF&F timers failed.
			(2) RCS valve sticking, roll valve deterioration.
C3XD-02	11-26-68	Success	(1) AF&F trigger circuit failed.
			(2) FS roll valve minor leak, FS and SS gas generator relief valve allowed pressure delay, ES valves long slew and delays, RBs experienced unsatisfactory trim angle of attack.
C3XD-03	1-21-69	Failure	(1) Lost FS conduit, lost SS conduit.
			(2) FS roll valve leakage.
C3XD-04	2-19-69	Success	(1) AF&F timer failed.
			(2) Large trim increase on DW at jacket removal, RCS valve sticking, SS TVC turbine speed drop for 5 sec.
C3XD-05	3-20-69	Success	(1) Guidance computer anomaly.
			(2) AF&F impact crystal output not observed, FS roll valve degraded performance, FS turbine speed low, large trim angle with step decrease during reentry.
C3XD-06	4-9-69	Failure	(1) HPU gear box failure (85 sec) causing missile failure.
C3XD-09	5-24-69	Success	(1) AF&F failure (loss of 500v to trigger CKT).
			(2) Flight control sequencer skipped gain state 5.
C3XD-10	6-14-69	Success	(1) RB separation delay (50.3 sec).
			(2) Popping dome "mystery spike" after second ignition.
C3XD-11	8-9-69	Success	(1) FS HPU turbine speed problem, SS HPU turbine speed problem, sequencer gain state 5 skipped, SS ignition "mystery spike."
C3XD-12	8-21-69	Success	(1) RB body released late (16.2 sec), RB body release slow (80 ms).
			(2) "Mystery spike."
C3XD-13	9-17-69	Failure	(1) Lost +30 vdc elex and arm control power 23 ms after thrust termination, decay of ignition inverter output monitor 55 ms after thrust termination, no STAS — RB not released, guidance computer scrambled.
C3XD-08	11-3-69	Failure	(1) Ignition inverter output decayed to 50 percent output due to thrust termination pyro shock, STAS sent but not received to DW (interlocks short).
C3XT-17	11-26-69	Success	(1) RB separation delays; all had normal fire commands, RB telemetry battery activate via g-switch failed.
C3XT-18	12-16-69	Success	(1) None. EAG-154
			(2) None.
C3XT-19	1-23-70	Success	(1) LJA-9 AF&F height of burst (HOB) option not obtained.
			(2) ES aft cable tray door opened early (0.1 sec after thrust termination)

POSEIDON (C3X) FLIGHT TEST SUMMARY (Continued)

Missile Number	Date/ Site	Success/ Failure	Problem/Anomaly
C3XT-20	2-4-70	Failure EAG-154	(1) Inadvertent auto destruct activation 939 ms after thrust termination. (No IFS; no RB separation)
C3XT-22	3-24-70	Failure EAG-154	(1) RCS valve command inhibited due to short on monitor command line in the FCEP.
C3XT-21	5-14-70	Success	(1) None.
C3XT-23	6-17-70	Success	(1) None.
C3XT-24	6-29-70	Failure	(1) NF failed to separate at the programmed time, channel B of destruct system failed at 166 sec.
C3XT-25	Launch Cancelled		
Note: Vehicles C3X-7, -14, -15, -16			Manufacture cancelled.
C3P-PEM-1	8-30-70	Success	SSBN-627
C3P-PEM-2	8-17-70	Success	SSBN-627
C3P-PEM-3	9-8-70	Success	SSBN-629
C3P-PEM-4	9-21-70	Success	SSBN-629
C3P-PEM-5	10-6-70	Success	SSBN-629

*The XD and XT designations indicate development and tactical configurations, respectively.

PEMs are Production Evaluation Missiles.

POLARIS (A3) ANTELOPE (A3T) DEVELOPMENT FLIGHT TEST — SUMMARY (1966 - 1968)

Missile Number	Date/ Site	Primary Objective	Success	Result Partial Success	Failure
A3TX-01 (A3P-492)	11-17-66 FP 29A	Basic vehicle; SS deviation; threat tube evaluation; reentry systems development.		X	
A3TX-02 (A3P-496)	1-6-67	Basic vehicle; Sandia development; threat tube evaluation; arming, fuzing, and firing (AF&F).	X		
A3TX-03 (A3P-514)	11-29-67 EAG-154	Radar observable signature. Kwajalein	X		
A3TX-04 (A3P-531)	3-2-67	Basic vehicle; threat tube evaluation; AF&F; reentry systems development.	X		
A3TX-05 (A3P-544)	12-6-67	Radar observable signature.	X		
A3TX-06 (A3P-558)	5-17-67	Basic vehicle; threat tube evaluation; AF&F; reentry systems separation and dynamics.	X		
A3TX-07 (A3P-573)	6-21-67 EAG-154 Kwajalein	Radar observable signature.	X		
A3TX-08 (A3P-588)	6-21-67 EAG-154 Kwajalein	Radar observable signature; AF&F.			X
A3TY-01 (A3P-613)	9-12-67 FP 29A	Sandia RB development; threat tube evaluation; basic vehicle, AF&F; radar observable signature; reentry systems separation and dynamics; reentry threat evaluation.			X
A3TY-03 (A3P-083)	11-1-67 FP 29A	Sandia RB development; threat tube evaluation; AF&F; basic vehicle, reentry systems separation and dynamics; reentry threat evaluation.		X	
A3TY-04 (A3P-091)	3-16-68 EAG-154 Kwajalein	RB dynamics and structure; AF&F; RB thermodynamics; radar observable signature; threat tube evaluation.	X		
A3TY-05 (A3P-102)	4-4-68 EAG-154 Kwajalein	RB dynamics and structure; AF&F; radar observable signature; threat tube evaluation; selector comparison.	X		
A3TY-07 (A3P-654)	4-11-68 EAG-154 Kwajalein	RB dynamics and structure; RB thermodynamics; RB separation; threat tube evaluation, system evaluation; reentry systems development.	X		
A3TY-06 (A3P-103)	4-19-68	RB dynamics and structure; RB development; radar observable signature; system evaluation.		X	
A3T-208	8-29-68 SSBN-626 ETR	Regular DASO missile.	X		
A3T-347	8-29-68 SSBN-626 ETR	Regular DASO missile.	X		

POSEIDON (C3) REENTRY BODY SUPPLEMENTAL FLIGHT TEST PROGRAM

Flight No.	Date	Configuration	Comment
1	9-22-66	Silica phenolic nose; beryllium body; VHF telemetry.	First successful flight test of small high beta RB. Reentry velocity equivalent to 2000 nm flight.
2	10-7-66	Silica phenolic nose; beryllium body	Successful demonstration at reentry velocity equivalent to 3000 nm flight despite booster anomaly causing high initial angle of attack (75 deg).
3	11-7-66	Silica phenolic nose; beryllium body.	Success — equivalent to 3200 nm range.
4	11-10-66	Shell and nose of silica phenolic.	Success. Some increase in RB roll rate during reentry.
5	2-24-67	ATJS graphite nose; beryllium shell.	Successful flight. Hyper sonic trim angle of attack was unusually small during reentry, indicating high stability. Late transition was experienced.
6	4-7-67	Silica phenolic nose; thinned down beryllium shell.	Success. Moderately high transition altitude. Roll rate decreased through zero.
7	5-5-67	Long carbon (ATJS) nose; ultra-thin beryllium shell.	Booster failed — no test.
8	8-24-67	ATJS "T" bolt nose; thin beryllium shell; new UHF FM/FM telemetry system; new AF&F; new single point separation system.	Booster failed — no test.
9	9-28-67	Same as No. 8.	Success: First RB to reenter with essentially no blackout, due to use of UHF telemetry. Moderate transition altitude. Trims larger than anticipated. Vehicle spun through zero.
10	11-9-67	Same as No. 8.	Success. Trims larger than anticipated. Very low transition observed. AF&F functioning partially achieved.
11	11-9-67	All beryllium (nose and body).	Booster failed — no test.
12	11-14-68	Improved ATJS nose; beryllium shell; PCM TLM. No delay link.	Failure. RB broke up during reentry possibly due to damage suffered at separation from Athena. First successful UHF-PCM usage Some AF&F data.
13	12-12-68	Same as No. 12. Telemetry was FM/FM prime with PCM secondary.	Successful low velocity jacket removal. Significant radial transition asymmetries noted. AF&F operated.

THE EXPANDING YEARS (MID-1971 - 1979)

The POLARIS A1 missiles had been completely retired from the Fleet by 14 October 1965. They had served their purpose as President John F. Kennedy's "trump" during the "Cuban Missile Crisis."

The POLARIS A2 began to be replaced (9 January 1968) in the Fleet by POLARIS A3. The last A2 patrol (SSBN-611) was completed on 9 June 1974.

The POLARIS A3 with its nominal 2500 nm range had completed its Blue Ribbon Recertification Program in 1968. The upgrade to harden POLARIS A3 to A3Ts (as a result of the ANTELOPE Program) was underway, to be completed by 20 March 1972.

The POLARIS C3 with its 14 MIRV reentry systems and 2500 nm nominal range had began deployment on 31 March 1971.

The DoD's STRAT-X/ULMS study had been completed in the summer of 1967 but the Navy's SPO — SSPO as of 1968 — continued its own ULMS study of an improved FBM (IFBM), either a Longer Range C3 (LRC3) or a new missile.

However, before continuing the discussion of the ULMS program and the resulting TRIDENT System, it would be appropriate to mention that, since the initiation of the POLARIS program (1955), Lockheed was involved in studies of many variants of FBM missile systems. Lockheed conducted on its own, or under SPO sponsorship, many missile/reentry studies, usage/targetting concepts, deployment and basing concepts, and several test/experiment programs. Some of the more prominent:

1957 — **Air Launch POLARIS.** Martin "Seamaster" (amphibious) aircraft with one POLARIS A1 missile per aircraft, global range with endurance increased by sea-sitting.

1960 — **Dolphin.** A torpedo tube launched nuclear missile; 21 in. diameter, 246 in. length, 4,115 lb launch weight with a 800 nm range, for use in fleet submarines.

1961 — **Stingaree.** An unmanned underwater basing system of POLARIS missiles secured to the off-shore ocean bottom. Each missile stored in an encapsulated vertical launcher secured to the ocean bottom. A North Atlantic Treaty Organization (NATO) deterrent missile.

1962 — **A2N (NATO) — Advanced A2.** Advanced version of the POLARIS A2, NATO applications used on Victory class merchant ships. Will operate on the high seas, coastal and inland waterways. 25 ships, 8 POLARIS per ship, modularized weapon system equipment, mixed nation crew (political problems generic to this program).

Also known as (aka) — MERSHIP

1962 — **Pen-Aids.** It was during this time frame that the first (PX-1) of many FBM Pen-Aid programs started for POLARIS A2. The follow-on programs PX-2, IMPALA, various POLARIS B3D systems, SSA (Subsystem A), PAP Penetration Aid Program (PAP), Mark 500, Large Accurate Evader (LAE), etc., will be discussed later in this document.

1962/63 — **Turtle.** A manned mobile submersible capable of operating on or near the ocean bottom. The original concept was a 1,000 ft depth. An advanced design extended this to 8,000 ft depth. It was a lenticular-shaped vessel, 65 ft in diameter and 35 ft in height. It would carry vertically six POLARIS A3s or four B-3s (later called C3's). It had a nuclear reactor for power with a speed of 8 knots. A steam hot-gas generator launching system and, because of greater launch depth, the missile would be encapsulated.

A concept modification considered two (Air Force type) ICBMs stored horizontally with an encapsulated launch. All concepts had an 18-man crew (maximum).

1963 — **ADPAC Sea-Emplacement Dormant Concept.** Self contained encapsulated missiles "sowed" on the sea bottom in a horizontal "bottom" container. Command and control not firm.

1964 — **Bottom Mobile System (BMS).** Follow-on effort to Lockheed's Turtle project. Five configuration concepts — several pressure hulls in a hydrodynamic fairing or outer hull. Pressure hulls for (1) crew, machinery, equipment, etc.; and (2) nuclear power plan, motors, etc. The vehicle carries encapsulated missiles exterior to the pressure hulls but part of the fairing. Launch at depths down to 8,000 ft with speed of 15 knots with 20-man crew. Six encapsulated B3's (C3's) or 2 larger missiles.

1967-on **STRAT-X/ULMS**. Numerous missile and SSBN concepts.

1966/67 **IRISH SETTER**. Stellar Inertial Guidance System (SIGS) to improve POSEIDON C3 accuracy. A feasibility study which showed at 20 to 30 percent improvement. In July 1967, SPO directed that the C3 baseline include the capability to operate with and without SIGS. Ultimately, SIGS was not incorporated in C3 but was in C4.

1968 **POLARIS A3M**. To counter Chinese and Sino-Soviet threats by increasing target coverage of an A3P by 4 to 6 times by application of C3 developed technology. A3M is an A3T (ANTELOPE) with C3 Mk 3 RBs mounted on a post boost vehicle (PBV) with a reaction control system.

1968/69 **Long-Range C3 (LRC3)**. Investigate the feasibility of adapting major elements of the POSEIDON (C3) system to develop a long-range (4500 ± nm) minimum change C3. The missile could have been either a bare internal or encapsulated external stowage configuration.

1968/70 **C3B**. Concept of improving the C3 which would utilize independent third stages in a new missile front end. Technical areas were studied in sufficient depth to establish feasibility and generate the data needed for system evaluation and planning. The C3B missile combined unchanged C3 FS and SS with modified ESs. Repackaged C3 equipment and either a Mk 3 or Mk 4 guidance system were in the modified ES. Seven independent TSs, each with two Mk 3A RBs, slave guidance, control, and propulsion made up the new front end. Study results indicated that technical feasibility existed from the aspects of structures and control. C3B remained a concept.

1969 **Great Lakes Advanced Strategic System (GLASS)**. Semi-lenticular submersible barges deployed in the Great Lakes, bottom sitting, 10 to 20 POSEIDON missiles, battery powered, 200 nm range, crew size — 14 to 18.

1969 **A2/A3 Booster's Orbital Payload Capability**. Mission is to place various weight transit satellites into orbit at various attitudes using POLARIS A2/A3 using a majority of tactical components and minimizing development effort.

1969 **Project "Long Shot."** Concept for a survivable backup VLF communications link between CONUS and FBM submarines in patrol areas. It was to provide backup VLF communication link between CONUS and FBM submarines on patrol by placing VLF transmitters over operational patrol areas using A3 boosters launched from submarines. "Long Shot" was determined to be a credible low-risk technique for providing a backup VLF communications link.

1969/70 **Sea-Based Anti-Ballistic Missile Intercept System (SABMIS)**. A concept of interception of missiles in their boost or mid-course phase using POSEIDON missiles as the interceptor was proposed. The system would have been installed on surface ships mounting phased array radars similar to those which were developed for the Nike-X system. Even in 1969, the outlook for development, much less the deployment, of the system was poor.

1969/70 **GREYHOUND CONCEPT**. Unsolicited proposal to the Air Force, of an air mobile basing system. The concept utilized a C-5 aircraft and a virtually unmodified POSEIDON C3 missile. Launch is achieved without aircraft modification by conventional air-drop parachute extraction of a missile/platform and missile-ignition when the aircraft has achieved a safe distance from the missile and its planned trajectory. The combination of CONUS basing, related aircraft radius of action, and 2500 to 3000 nm stand-off missile range provides a coverage of 25 major USSR urban-industrial complexes. Initial test demonstrations would use a C-130 aircraft and inert A2 missiles followed by live A2 missiles. The C5A would carry three C3's. The concept was revisited in 1971, updating the proposals analysis to include continuous airborne alert deployment.

1970 **POSEIDON Ballistic Missile Ship (BMS) System.** "Seamaster" class of merchant ship, 1900 nm range, 24 knot cruise, 40-man crew, six team POSEIDON C3 missiles per ship, modularized weapon system equipment installation.

1970 **C3 Alternate Front End (CAFE).** A study program which would have developed alternate payloads for POSEIDON C3 missiles. Three program options were identified. These options assumed MIRVs would be banned either on 1 November 1970 or 1 July 1971. They were programs which involved outfitting SSBN POSEIDON conversion submarines with either the C3PT (one Mk 3 reentry body) missile, a C3 missile using the A3's Mk 2 reentry body configuration, or a C3 with a Mk 1 reentry body. Ultimately, there was no ban on MIRVs and POSEIDON C3 missiles were deployed as originally scheduled.

1970's to Mid-1983 **Shallow Underwater Mobile/ Small Underwater Mobile (SUM).** Continuous controversy over MX basing gave rise to various concepts (non-Navy/DoD) of small submarines with a few external, encapsulated MX missiles. A CNO 1979-80 directed evaluation (SSP/ LMSC) concluded that there were many major concerns and areas of uncertainty and, thus, recommended no further studies of this concept at the time.

1974 **Controlled Reaction Force (CRF).** A small (1400 ton) U.S. continental shelf sitter, tethered (umbilical) to a power source, battery and external power, 100 nm cruise range, crew of 12, four C4 missiles encapsulated storage, improved accuracy by launching from pre-surveyed bottom sites.

1974 **Reloadable Missile.** Slightly larger 640 class SSBN, deployed with C3 or C4 missiles, plus additional inclined launch tubes with at sea reloadable missiles — 35 in. diameter, 27 ft long, 1500 lb, 3650 nm range, 36 to 46 missiles per SSBN.

Returning to the Subject of STRAT-X/ULMS. Just as project NOBSKA in 1956 "steered" the U.S. Navy to a new generation of smaller solid-propellant POLARIS-type FBMs, so too STRAT-X/ULMS "steered" the Navy to the next generation SSBN/ FBM system.

To repeat some of what has been presented in the previous chapter, SECDEF Robert McNamara, on 1 November 1966, initiated a comprehensive study on U.S. ballistic missile basing concepts and missile performance characteristics required to counter potential Soviet strategic offensive forces and anti-ballistic missile proliferation in the time frame 1975 to 1985 — 90.

The study was conducted under the auspices of the Research and Engineering Support Division of IDA. The study was known as STRAT-X (for STRATegic eXperimental).

Based on a previous study done by the IDA earlier that year called PEN-X (for "penetration of enemy missiles, experimental"), the deliberately-nebulous title was concocted to prevent bias in the study toward any land-, sea-, or air-based system. Positing the likelihood that the Russians would deploy, in the future, extremely-powerful and highly-accurate ICBMs as well as an effective anti-ballistic missile system, McNamara's study requested appropriate countermeasures. The STRAT-X study was headed by General Maxwell Taylor, President of IDA. The "working" study group was headed by Fred Payne of IDA.

The "working" panel included executives from several major defense contractors and independent corporations. The Advisory Committee were mostly military men. RADM George H. Miller (OPNAV) and RADM Levering Smith, (SP-00) — the Navy contingent on the STRAT-X panel, "representing both the [Naval Operations] staff and the 'hardware' side of the Navy" — participated, but Naval Reactors Branch, which furnished the nuclear power plans for all nuclear-powered Navy vessels, did not.

STRAT-X STUDY
FRED PAYNE — DIRECTOR
(DDR&E) (OSD)

ADVISORY COMMITTEE
MGEN BETTS (AF) (R&D)
MGEN KENT (AF) (R&D)
DR. LATTER (RAND)
MGEN McCOY (AF)
RADM SMITH (SP)
RADM MILLER (OPNAV)
DR. WHEELON (HUGHES)

STEERING COMMITTEE
WILCON (DDR&E) (OSD)
EASLEY (DDR&E) (OSD)
SELIN (S/A) (OSD)
FRIEL (ARPA)

DESIGN PANEL
RINEHART (MARTIN)

PENETRATION SYSTEM DESIGN
DUNN (BOEING)
TRUDEAU (AF)
GORDON (IDA)

MISSILE DESIGN
MUNSON (GD/CONVAIR)

BASING CONCEPTS
DEPROTINE (DOUGLAS)
ABM
DRAKE (NORTH AMERICAN)
ULM
FIEDLER (LOCKHEED)
ULM
COX (BOEING)
SILO
HARRIS (GD/QUINCY)
SLM

EVALUATION PANEL
YARBROFF (SRI)
CAPPS (AEROSPACE)

ANALYSIS
PENNINGTON (AFWL)

PAYLOAD EVALUATION
PERRY (GE)

NUCLEAR EFFECTS
SUSSHOLZ (TRW)

COST
ALLEN (IDA)

REACTION PANEL
CUMMINGS (ELECTRO-OPTICAL)
KAHN (IDA)

SOVIET RESPONSE
SCHULTIS (IDA)
NOLEN (IDA)
TURNOFF (IDA)
FINKE (IDA)
WHITT (CNA)

MILITARY INTELLIGENCE
CRIST (IDA)

WEAPON EFFECTS
BARFIELD (IDA)

SOVIET PAYLOADS
OLIVER (IDA)

Candidate STRAT–X system concepts were evaluated for:

1. (Primary) The ability to retaliate against a Soviet urban–industrial target
2. (Secondary) Flexibility to perform selected counterforce and controlled–response missions.

STRAT-X investigated and reviewed over 125 different missile-basing systems for the purpose of finding the most efficient and survivable option, the only prerequisite being that the candidate system had to be unique in comparison with previous or existing platforms. Going into the study, the Air Force had lobbied for a replacement for the Minuteman ICBM, and it appeared initially as though the Air Force missile might be chosen, but the requirement for new ideas also worked in the Navy's favor.

STRAT-X STUDY CALENDAR

Event	Date
	1966
1. Review of STRAT-X Study Groundrules	30 Nov
2. Review of Systems Selected for Study	19 - 20 Dec
	1967
3. Review STRAT-X Study Findings	15 - 16 June
4. Disband Study Group	1 Jul
5. DoD Briefings (by Mr. Payne)	1 - 31 Jul

Some of the candidate systems proposed/studied:

A. Fixed Undefended
   1. Proliferation of Hardened Minuteman III
   2. Silo Launchers Deployed in Rock
   3. Rock Tunnels With Mobile Missiles
   4. Dirt Tunnels With Mobile Missiles

B. Fixed Defended (Radar, Short/Long Range Interceptors)
   1. Defended Minuteman III
   2. Defended, Hardened, Minuteman III
   3. Defended, Silo Launchers in Rock
   4. Defended Rock Tunnels With Mobile Missiles

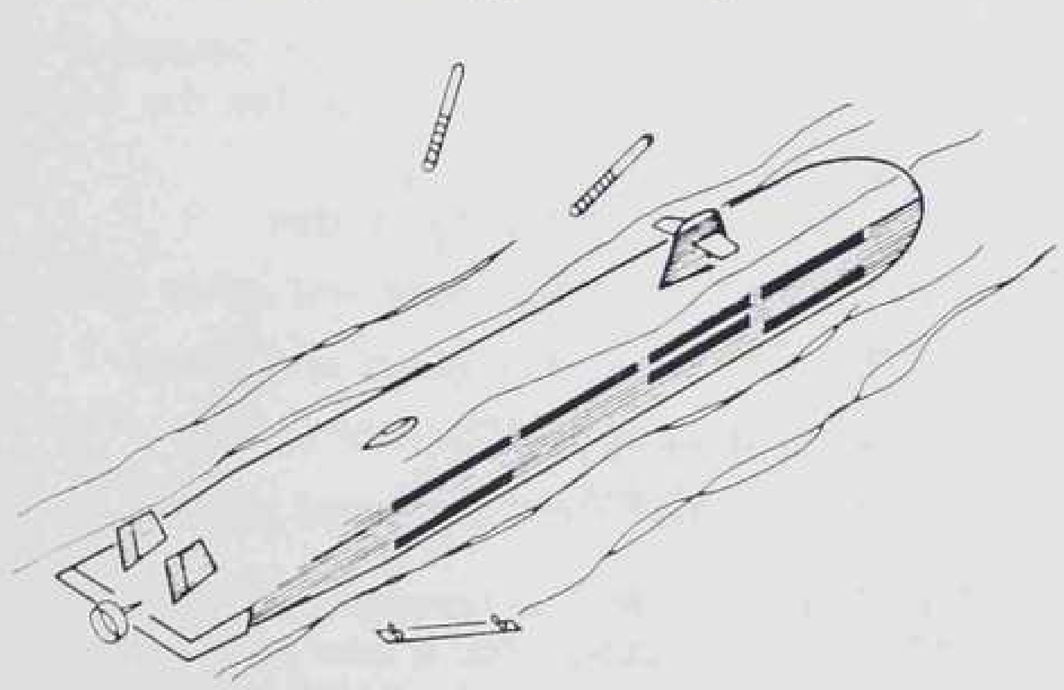
C. Land Mobile

D. Ship Based

E. Undersea Based
   1. Proliferation of POSEIDON
   2. ULMS.

Other than submitting an improved POSEIDON, the Navy STRAT-X study teams under Dr. Willie Fiedler of Lockheed proposed a different submarine concept called ULMS. After examining these and other alternatives that ranged from the sublime to the ridiculous (such as missile-firing submersibles, ICBMs carried on trucks, surface ships or barges, new bombers, seabed platforms (perhaps located in Hudson Bay)), the STRAT-X panel concluded in 1968 that the Navy's ULMS represented the least costly and most-survivable alternative. Miller claimed the panel envisioned a "rather austere" ship with little speed and, consequently, a small nuclear power plant. The Navy supported the view that "ULMS was to incorporate very-long-range missiles into submarines of rather conservative design, based on existing submarine technology .... The proposed submarine would not necessarily be deep-diving ... and would carry more than sixteen missiles." At least one ULMS proposal featured missiles carried horizontally outside the submarine's hull.

The missile ranges would be longer, enough longer that the system is CONUS-based. The system carries in the order of 3,000,000 lb of throw-weight packaged into 32 submarines carrying 24 missiles, each with approximately 4000 lb throw-weight per missile. The missiles are to be in 8 groupings of three encapsulated missiles, all external to one pressure hull. The overall length of the ship is approximately 400 ft with a 55 ft beam and a depth of approximately 40 ft.



ULMS Submarine

Various concept tradeoff studies of the ULMS were conducted (Electric Boat and Lockheed supported), considering number of submarines-versus-number of missiles-versus-number of RBs-versus-range-versus-throwweight-versus-targetting-versus-effectiveness-versus-operating area-versus-accuracy, etc.

These ULMS missile studies tended to culminate in either a 2 or 3 stage missile with a 4500 nm range and a weight in the order of 130,000 lb. Since the missile was to be encapsulated and external to the SSBN, it was size limited. This led to a new FBM missile concept approximately 80 in. in diameter and 56 ft in length. The missile was referred to as LRC3 (Long Range C3) and Lockheed's concepts included a new RB (Mk 3A). About this time, the ULMS began to be known as the Improved Fleet Ballistic Missile (IFBM) system.

Studies related to the proliferation of POSEIDON C3 led to the conclusion that a new ULMS (missile) and the new submarine concept with greater missile carrying capacity would make the ULMS (missile) more cost-effective than POSEIDON proliferation.

ULMS FOLLOW-ON

Upon completion of the DoD's STRAT-X Study, the Navy (SPO) continued its own studies of advanced undersea system concepts. Lockheed, General Electric, MIT, Sperry, and Westinghouse were all involved. Electric Boat was funded by Navships for interfacing submarine studies. The SPO was redesignated SSPO on 29 July 1968. The ULMS program was established by the CNO on 4 October 1969. The ULMS Project Manager (PM-2) was established under the CNM on 31 March 1971.

His responsibility was for the entire ULMS under the CNM. The SSPO as PM-1 was responsible for the strategic missile system (e.g., missile, fire control, guidance, launcher, navigation, etc.). NAVSEA was responsible for the ULMS submarine per se. Each of them submitted the resource requirements, etc., to PM-2 as the ULMS coordinator for the CNM.

As stated before, subsequent to STRAT-X, the ULMS effort was continued by SSP at DDRE direction. The cost of concurrently developing a new submarine and missile was judged to be inconsistent with DoD funding and dedication. Since the submarine is the long lead item (seven years from funding to IOC), minimum subsystem changes were dictated for the new submarine.

The submarine design work subsequent to STRAT-X was directed along the encapsulated missile concept as opposed to the FBM concept of bare vertical launch from a fixed mount tube. RADM Levering Smith, PM-1, stated that the encapsulated missile would be retained only if real merit could be established. Electric Boat was requested by CAPT Gooding (SP-20) to do a submarine feasibility study for both bare vertical and encapsulated stowage and launch of the LRC3 missile. Missile length and FS diameter are dependent variables. Each concept was allowed to consider dimensions best suited to the stowage mode. The trend for vertical stowage was to make the missile short, and the trend for horizontal encapsulated stowage was to make it long until it hurts. The tradeoffs between launch mode concepts were conducted during CY 1968.

In January 1969, the contractors involved in the stowage mode studies presented their data to SSP. CAPT Wertheim had replaced CAPT Gooding as SP-20. CAPT Wertheim noted that the Ship people favored bare vertical, while the Missile people favored encapsulated. RADM Smith, PM-1, decided that SSPO would recommend bare vertical launch and stowage. NAVSEC, NAVSHIPS, and DDR&E concurred, and the decision was made.

An SSPO Memorandum of 26 May 1967 outlined some ULMS program decisions and determinations intended to assist studies of candidate SSBN hull forms. Some of these were:

1. Preferred number of missiles per ship
2. Launch tube diameter
3. Missile access
4. Launch tube arrangement
5. Ship/subsystem interface
6. Maintenance concepts.

Both Electric Boat (Groton, Connecticut) and San Francisco Bay Naval Shipyard (Mare Island (Vallejo), California) were requested to provide ULMS SSBN concepts.

By December 1969, the ULMS team at Mare Island had developed three basic hull forms, concentrating their efforts on developing an external launch tube hull.

Two of the Mare Island designs, the "FISHBONE" and "D Frame" concepts, involve advanced SOTA pressure hull construction techniques. The FISHBONE concept, in the missile section, is configured to present a non-circular pressure hull. It was conceived to use the inboard half of the missile tube as the primary pressure hull in the missile tube section of the boat. The "D Frame" achieved a similar non-circular missile tube section by using a flat plate technique outboard of the missile tube as one portion of the hydrostatic hull.

The third concept, "TWIN TUBE," is Mare Island's preferred configuration. In this hull form, the missile tubes (located in the water) have port and starboard access tubes running fore and aft that provide access to the fore and aft part of the boat, as well as access to the missile tubes (Figure D–1).

Four IFBM hull configurations were offered by Electric Boat, one "external" (wet) tube design and three "internal" tube design: single hull, double hull, and oval hull. The three tube abreast oval hull design had a variant configuration, two tube abreast (Figures D–2 and D–3).

There were also studies made of tilting the launch tubes athwartship and/or fore/aft attitude. The athwartship angle was limited to something less than ±10 deg from the vertical. The fore and aft angle could be varied quite a bit more (e.g. ±90 deg possible but not practical). A 50 deg fore/aft tilt was studied. However there was a general disbelief in any merits of loading and launching on any line that was not in line with gravity (e.g., vertical) (Figure D–4).

These studies were evaluated and Lockheed issued a report on 9 January 1970. It stated that the FBM Weapon System has always accepted the classic, POLARIS-POSEIDON 2 x 8 columnar, vertically-tubed, missile zero pointing center, battery arrangement. The data indicated no significant advantages, insurmountable problems or even significant sensitivity to various arrangements. This points to the practical position of "why change," when we might, with some assurance, find the unk-unks hidden within some other arrangement. It is these unk-unks that can react with negative synergism to create significant problems.

The report concluded then that the classic FBM battery arrangement should be maintained.

Various submarine and long-range missile studies continued at the request of the CNO. Finally the DoD Deputy Director for Research and Engineering requested the Defense Science Board (DSB) Strategic Task Force to review these Navy studies.

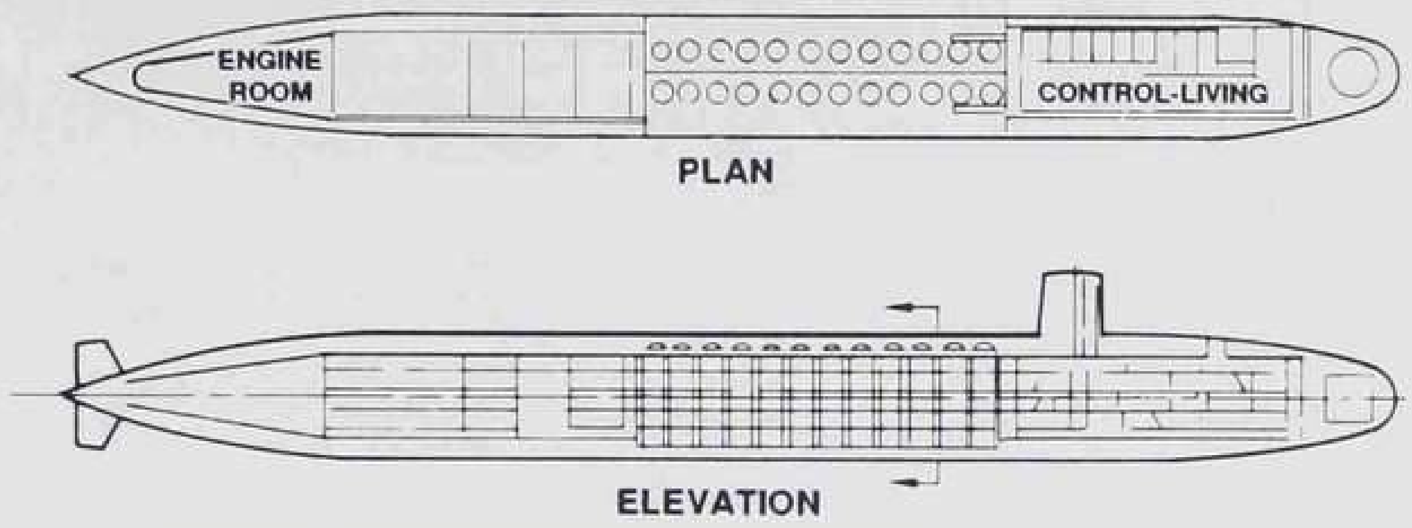
The Navy presented to the DSB in December 1970 to February 1971 that the reasons that the ULMS was needed were to:

1. Increase ocean operating area
2. Reduce submarine noise and other observables
3. Increase maximum speed and power
4. Replace aging POSEIDON SSBNs
5. Provide additional sea-based payload.

The DSB task force recommended that POSEIDON SSBNs be equipped with a new long-range missiles. They indicated that the Navy did not present a convincing case for speed, POSEIDON SSBN aging, or the need for more sea-based payload. The IOC for the Navy ULMS SSBN was estimated as 1981; hence the POSEIDON boats would have to be a major element of the strategic forces at least until the mid-1980's. The IOC for a long-range missile version of POSEIDON was estimated as 1976 or 1977. Thus, **even if a strong case could be made for a new submarine, the DSB task force would strongly recommend that Poseidon SSBNs be retrofitted with a long-range missile.**

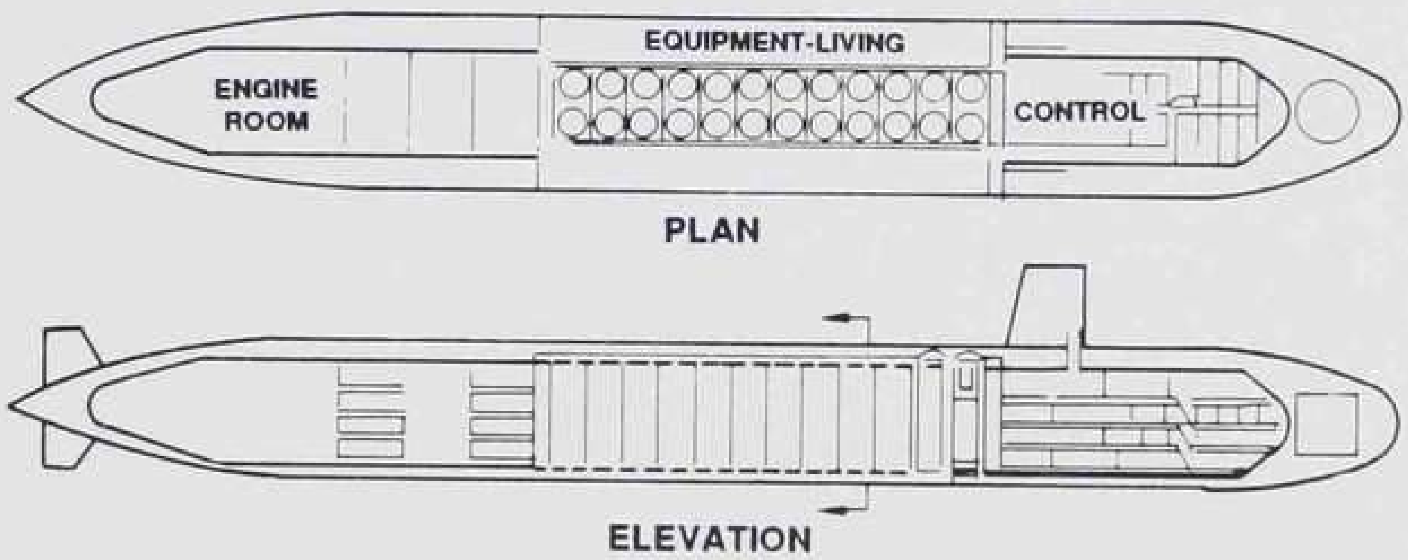
This task force stated that a cogent case for a new submarine had not been made. However, considering

MARE ISLAND "FISHBONE" CONCEPT (69-26)

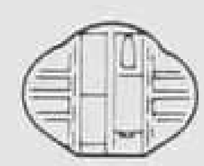


CHARACTERISTICS					
LENGTH	= 635 ft		HULL ENVELOPE	=	38,200 T
BEAM	= 56 ft		A-1 DISPLACEMENT	=	13,000 T
DEPTH	= 56 ft		PRESSURE HULL DIAMETER	=	40 ft
DRAFT	= 23 ft		NUMBER OF MISSILES	=	24

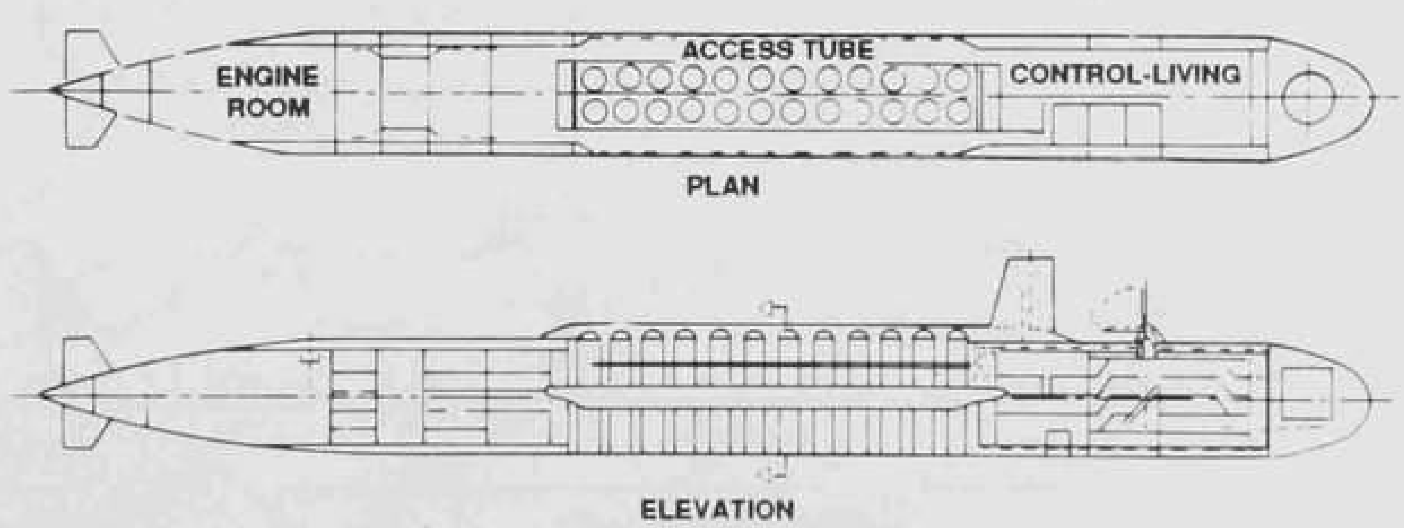
MARE ISLAND "D" FRAME CONCEPT (69-14)



CHARACTERISTICS					
LENGTH	= 567 ft		HULL ENVELOPE	=	37,910 T
BEAM	= 68 ft		A-1 DISPLACEMENT	=	16,100 T
DEPTH	= 55 ft		PRESSURE HULL DIAMETER	=	40 ft
DRAFT	= 27 ft		NUMBER OF MISSILES	=	24



MARE ISLAND "TWIN TUBE" CONCEPT (C9-22)



CHARACTERISTICS					
LENGTH	= 635 ft		HULL ENVELOPE	=	38,300 T
BEAM	= 56 ft		A-1 DISPLACEMENT	=	13,000 T
DEPTH	= 56 ft		PRESSURE HULL DIAMETER	=	40 ft
DRAFT	= 23 ft		NUMBER OF MISSILES	=	24

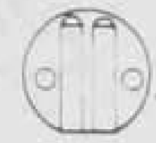
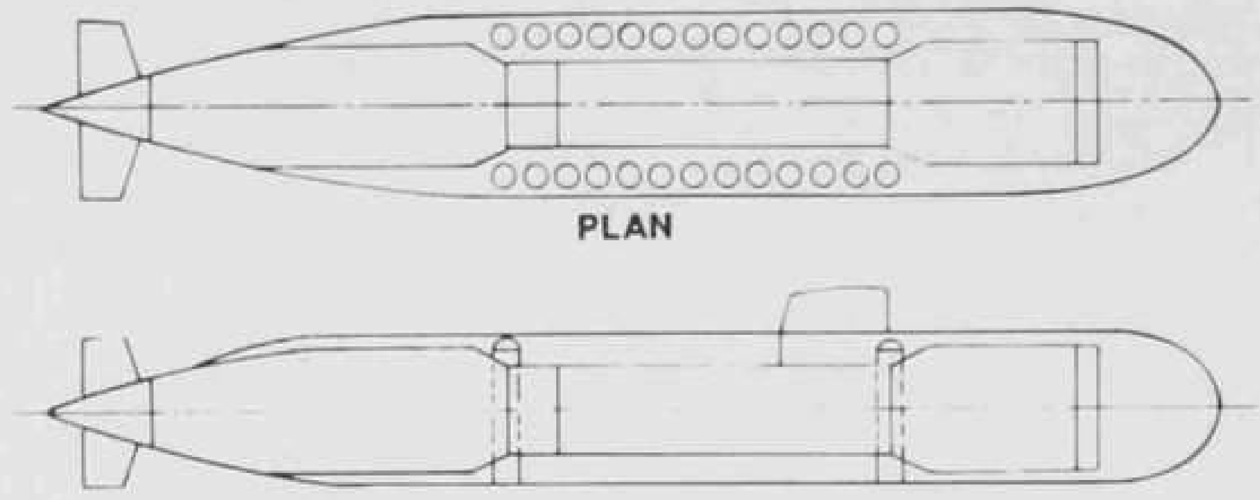


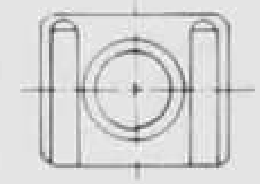
Fig. D–1 ULMS SSBN Concepts (Sheet 1 of 3)

ELECTRIC BOAT "WET TUBE" CONCEPT (005)

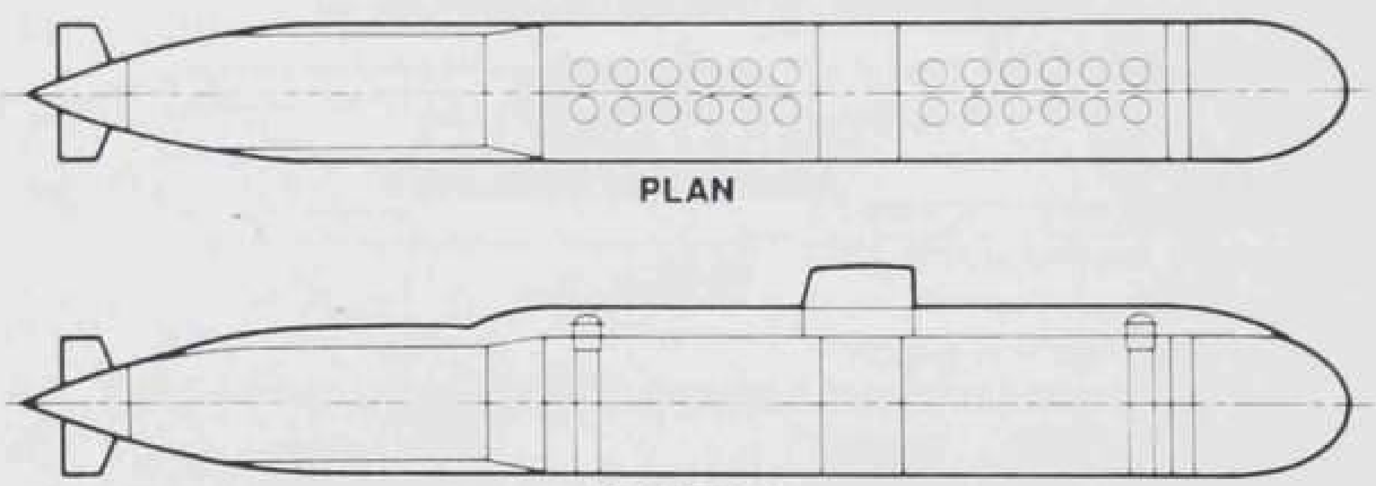


CHARACTERISTICS

LENGTH	= 484 ft	HULL ENVELOPE	=	29,200 T
BEAM	= 60 ft	A-1 DISPLACEMENT	=	11,400 T
DEPTH	= 56 ft	PRESSURE HULL DIAMETER	=	56 ft
DRAFT	= 32 ft	NUMBER OF MISSILES	=	24

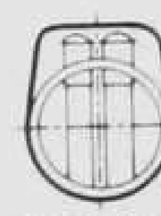


ELECTRIC BOAT "SINGLE HULL" CONCEPT (001)

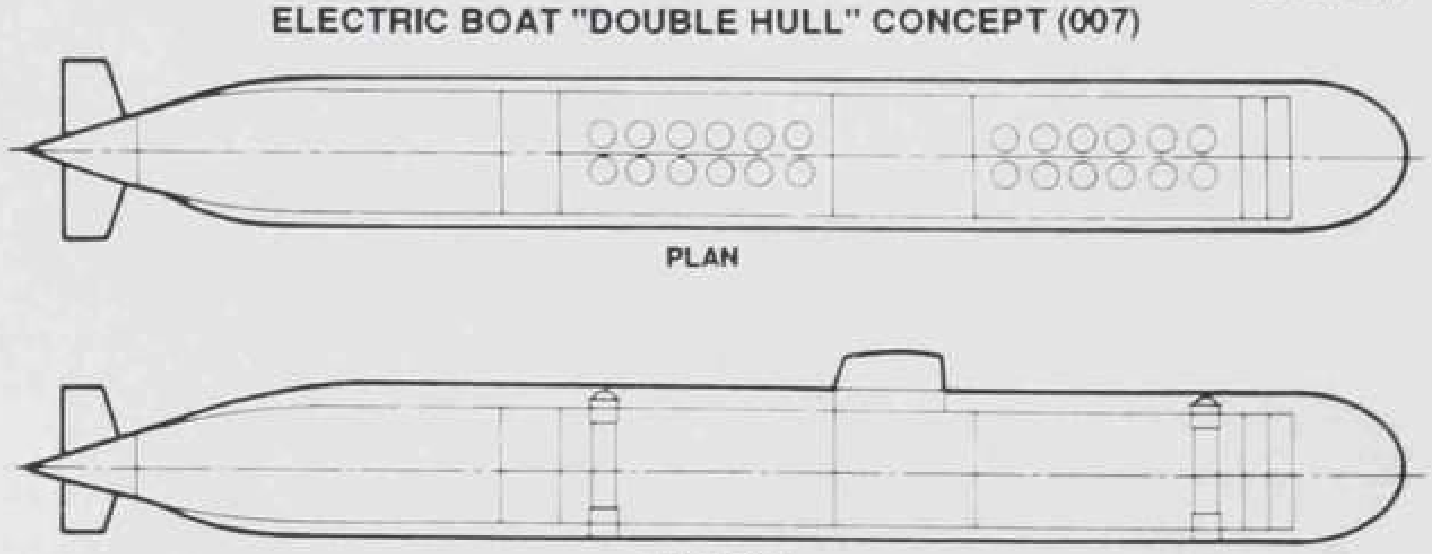


CHARACTERISTICS

LENGTH	= 471 ft	HULL ENVELOPE	=	24,400 T
BEAM	= 49 ft	A-1 DISPLACEMENT	=	12,500 T
DEPTH	= 59 ft	PRESSURE HULL DIAMETER	=	44 ft
DRAFT	= 42 ft	NUMBER OF MISSILES	=	24



ELECTRIC BOAT "DOUBLE HULL" CONCEPT (007)



CHARACTERISTICS

LENGTH	= 487 ft	HULL ENVELOPE	=	26,300 T
BEAM	= 50 ft	A-1 DISPLACEMENT	=	12,500 T
DEPTH	= 56 ft	PRESSURE HULL DIAMETER	=	44 ft
DRAFT	= 38 ft	NUMBER OF MISSILES	=	24

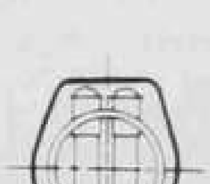


Fig. D–2 ULMS SSBN Concepts (Sheet 2 of 3)

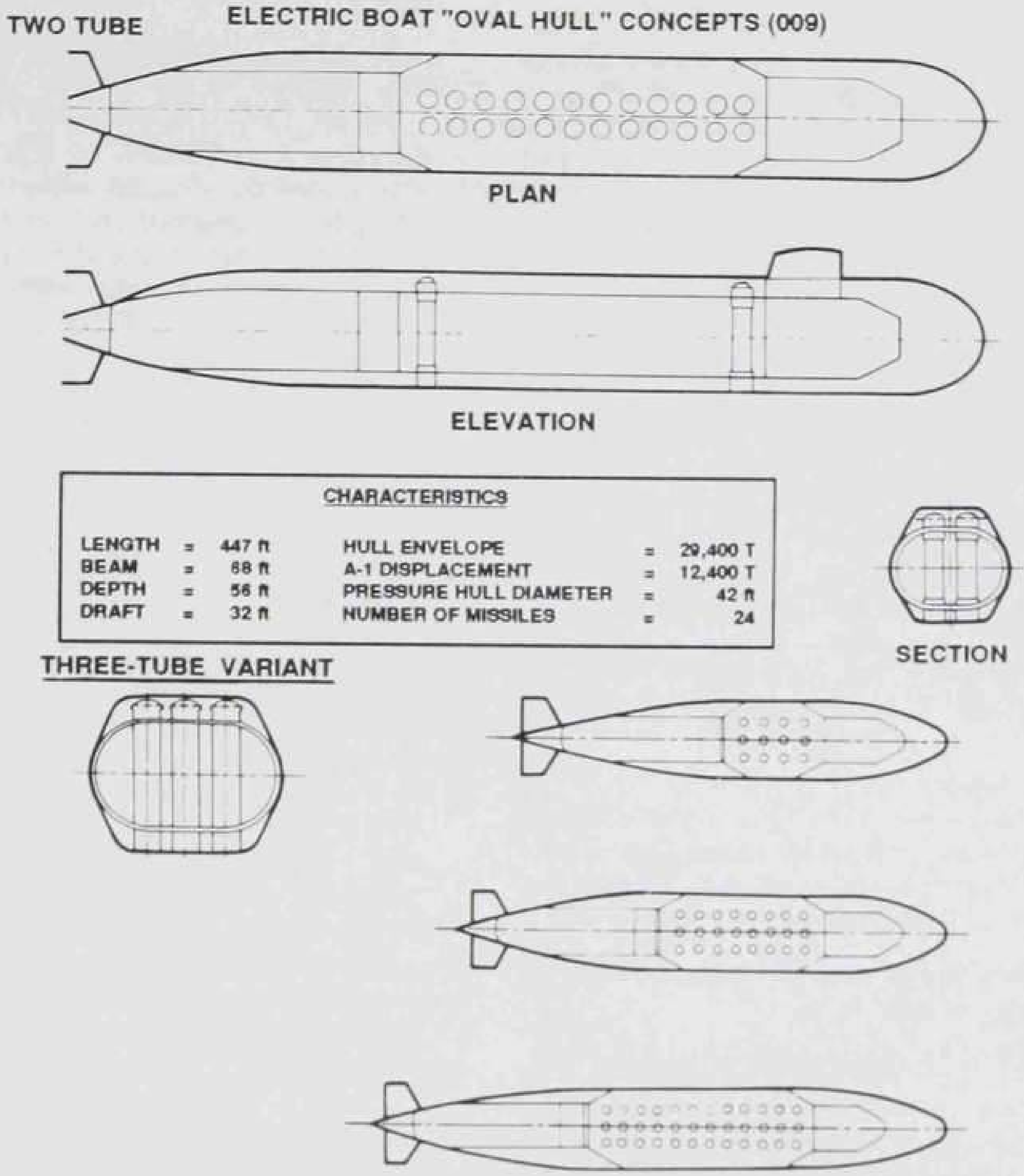


Fig. D-3 ULMS SSBN Concepts (Sheet 3 of 3)

Fig. D-4 Launch Tubes with 50 deg Tilt the long lead time required to develop a new submarine, and recognizing that the future is uncertain — the POSEIDON boats may be costly to maintain as they age or the Soviets may deploy a heavy anti-ballistic missile — that task force is inclined to support R&D effort on the ULMS SSBN program **in addition** to the development of a long-range missile for POSEIDON boats.

Lockheed had provided support to the prior submarine configuration studies but at the same time devoted efforts to evaluate various missile concepts (e.g., 4500 nm range but size limited to the space available in a POSEIDON SSBN launch tube). This basically required the new missile's envelope to be the same as the POSEIDON C3 (e.g., approximately 34 ft in length and approximately 74 in. in diameter but have a range of 4000 nm or so — versus — the postulated 2500 nm range of the POSEIDON C3, plus carry a payload equal to the C3 with the same accuracy.

At approximately this time, SSPO issued the following standard nomenclature to resolve confusion associated with the IFBM Program and the ULMS Program:

a. Undersea Long-Range Missile System (ULMS) for system designation.

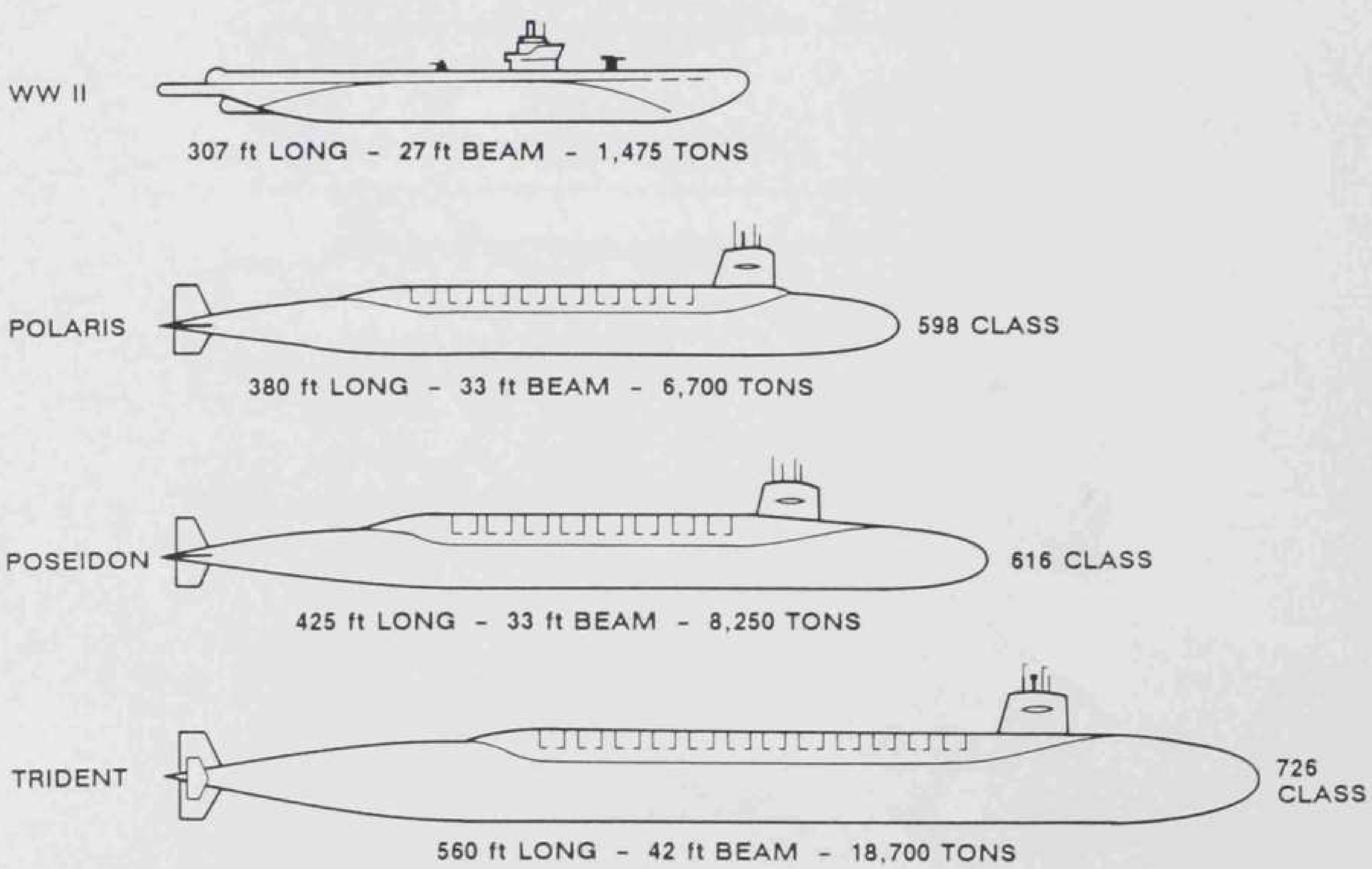
b. Improved SSBN for submarine subsystem.

c. Advanced POSEIDON for the initial missile subsystem.

Lockheed proposed to SSPO in October 1969 to study and analyze the advances in technology which have been achieved both within and outside the FBM program to determine the potential of these advancements to improve the FBM missile. Go-ahead was given Lockheed in February 1970.

Three important facts concerning American strategic defense capabilities had assumed a central significance in deliberations of U.S. defense planners. First, the submarine-launched ballistic system was recognized as the most survivable element in the triad of strategic nuclear deterrents. Second, though the POSEIDON missile provided an important upgrade of the system, the SSBN force itself was aging and would require replacement. Third, the threat of improved Soviet ASW capability made an enlarged SSBN operating area highly desirable.

It was in recognition of these facts that the Deputy SECDEF approved Development Concept Paper (DCP) No. 67 on 14 September 1971, outlining Navy plans for a new ULMS. The ULMS program was a long-term modernization plan which proposed development of a new, longer-range missile and a new, larger submarine, while preserving a nearer-term option to develop an extended range POSEIDON. In addition to the new ULMS (extended-range



Submarine Comparison

POSEIDON) missile, which was to achieve a range twice that of POSEIDON, the SECDEF decision described an even longer-range missile to be required for a new submarine, whose parameters it would, in part, determine.

This second missile, subsequently termed ULMS II, was to be a larger, higher-performance missile than the extended-range POSEIDON and to have a range capability of approximately 6000 nm. No further definition of its characteristics was deemed possible or desirable at the time, at least until the extended-range missile (Advanced POSEIDON) development was far enough along to provide a basis for confidently sizing the second-generation missile.

A Navy decision was made in November 1971 to accelerate the ULMS program with increased funding for the ULMS SSBN. The SECDEF Program Budget Decision (PBD) of 23 December 1971 authorized the accelerated schedule with a projected deployment of the ship in 1978.

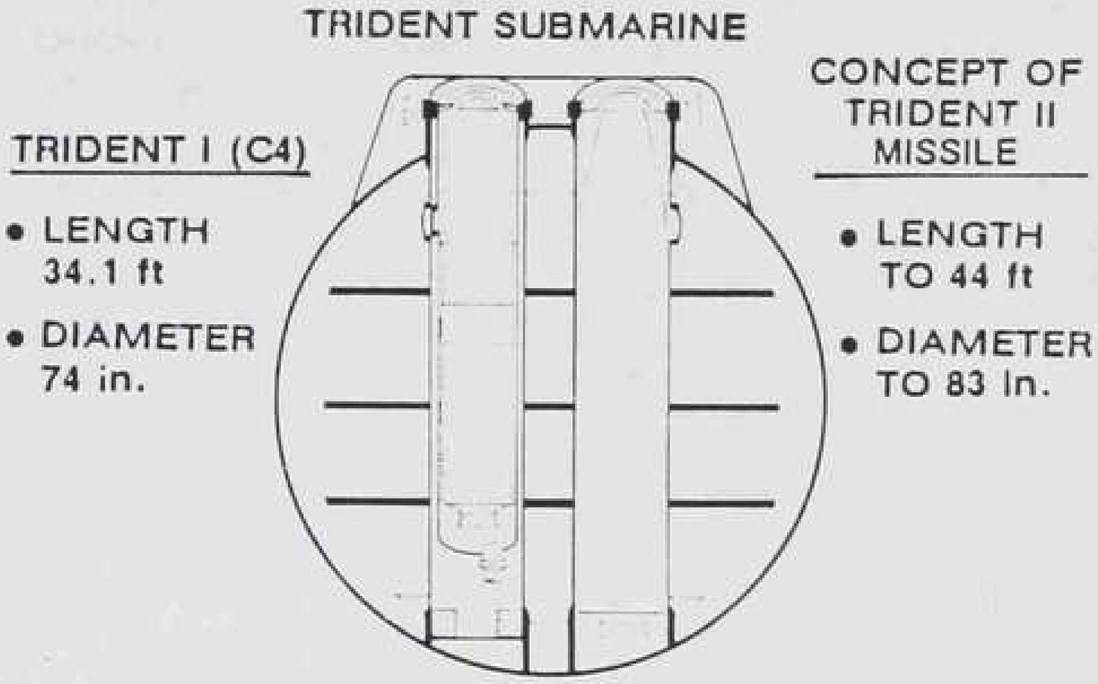
The term TRIDENT (C4) replaced the extended-range missile (Advanced POSEIDON) nomenclature by ASD direction in May 1972, and the name TRIDENT II was first officially used to designate the new longer range missile in the Navy POM submission for that year. The initial POM 74 outlined required funding for the TRIDENT II.

Lockheed commenced a TRIDENT I (C4) Advanced Development Program on 15 November 1971, which was the start date for contract N00030-72-C-0108. The IOC of the C4 was established as CY 1979. The IOC for the ULMS II missile (TRIDENT II) was set as FY 1984.

The SECDEF on 23 December 1971 approved Navy Program Budget Decision #317 to increase ULMS budget funding to permit acceleration of the program calling for deployment of a new class of SSBNs capable of carrying the 4000 nm TRIDENT I missile and, later, the 6000 nm TRIDENT II missile.

On 1 November 1973, Lockheed commenced the TRIDENT I (C4) Missile OSDP Program. The OSDP contract with Lockheed was not executed until 19 August 1974 but the effort since November 1973 was included. The contract was for missile system development plus the production of the first missiles, including RB shells. The contract provided for support equipment and technical services to outfit and support operation of TRIDENT I and backfit submarines, SWFPAC, POMFLANT, and training facilities.

As stated earlier, on 14 September 1971, the Deputy SECDEF had approved the Navy's DCP No. 67, which authorized both a new, large, higher-speed submarine and the TRIDENT (C4) Missile System. It was also constrained to fit in the circular SSBN cylin-



TRIDENT Growth Potential

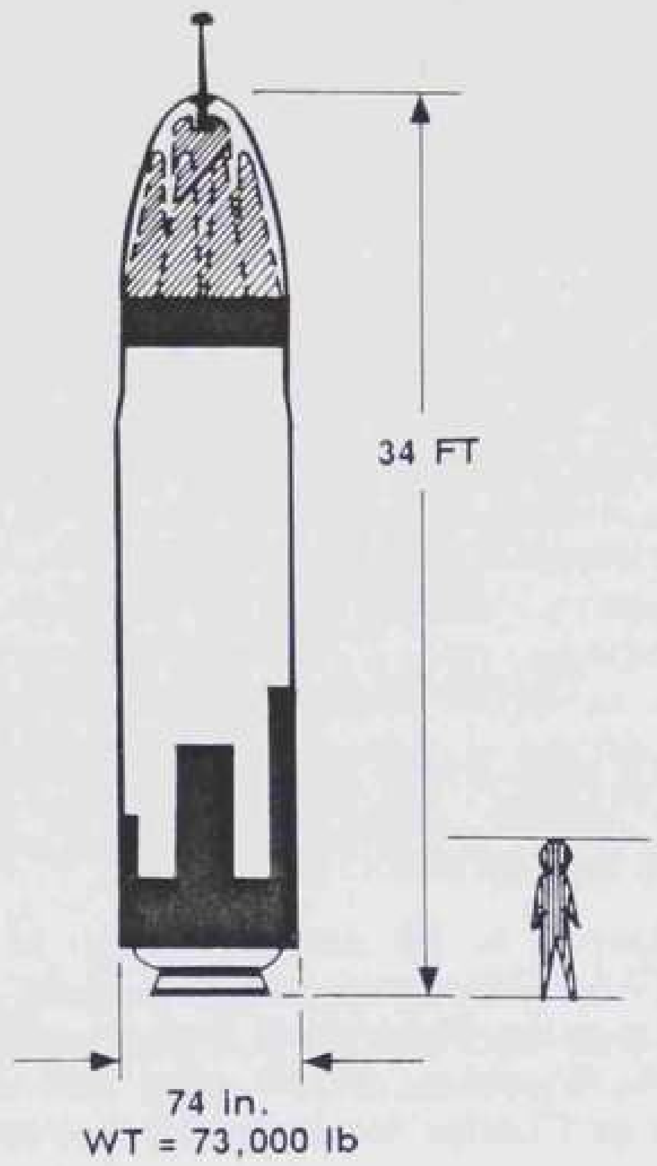
der launch tube which just contained the C3 so that the new missile could be used in then-existing POLARIS submarines.

The following is an excerpt from an article on TRIDENT I (C4) development written in 1980 by VADM Levering Smith (ret) formerly SP-00, RADM Robert H. Wertheim SP-00, and Robert A. Duffy, President of Charles Stark Draper Laboratory.

"The accuracy of the new missile system, to maintain effectiveness, was to be equivalent at 4000 nm to that of the POSEIDON C-3 at 2000 nm. To gain the increased full payload range, it was necessary to give up some of the maximum possible ABM exchange ratio which would only be of value should the then proposed ABM Treaty be abrogated. As a hedge against such a contingency, advanced development of a maneuvering, evader reentry vehicle capable of being carried by the missile was included in the program. The large, quiet submarine was to be called TRIDENT and the missile, to be carried in these submarines as well as in many of the earlier submarines, was to be called TRIDENT I — designated C-4.

"The major engineering challenges of the TRIDENT missile development, which required innovation as well as state-of-the-art advances, derived from the goals of doubling the missile range in the same volume and weight while keeping the already surprisingly good accuracy at this doubled range. Improving the accuracy involved navigation and fire control improvements as well as missile and guidance. Only the latter two will be discussed. In addition to these technological challenges, there were equally important design constraints derived from cost and reliability goals. Development costs were constrained in a period when inflation was high, and different in the various segments of the economy, while inventories were generally very low and lead times long. Production cost was an additional major design consideration and reliability (hence operational dependability) was, as always, given top priority.

"The largest contribution to attaining the range increase goal came from incorporating a third boost



FEATURES

- THREE POWERED STAGES
- KEVLAR MOTOR CASE
- 1 NOZZLE/STAGE
- THRUST VECTOR CONTROL
  - HYDRAULIC ACTUATION
  - FLEXSEAL NOZZLE JOINT
- THRUST TERMINATION - NONE
  - REPLACED BY GEMS
- STELLAR-INERTIAL GUIDANCE
- DEPLOYABLE AEROSPIKE
- 8 Mk 4 REENTRY BODIES ON
  - MANEUVERABLE EQUIPMENT SECTION (Mk 500 EVADER COMPATIBILITY)
- 4,000 nm BASELINE RANGE

Trident I — C4

propulsion stage. To fit within the same cylinder as the POSEIDON this third stage motor was to be mounted in the center of the post-boost vehicle as shown in Figure 1, with the reentry vehicles carried around the third stage.

"The strategy adopted to achieve the remainder of the range goal was to pursue range gaining technologies in the following general ways all in parallel

- Decrease inert weight throughout the entire missile
- Increase the volume available for propulsive energy
- Increase the usable energy per unit volume

"This strategy resulted in efforts directed to developing a smaller and lighter guidance system, lightweight missile structures, low volume and lightweight electrical and electronic components, smaller or lighter post-boost control system, an aerospike to reduce boost phase aerodynamic drag and, most importantly, higher performance rocket motors. In order to withstand reentry heating at long ranges and higher ballistic coefficients, new protection materials needed to be developed for the reentry vehicles.

"While both missile development and guidance development contributed to meeting the range goal, the larger gains were made by missile development. Similarly, both helped improve accuracy with the major responsibility for accuracy going to guidance development.

"Placement of the third stage motor in the center of the post-boost vehicle or "bus", presented new environmental demands on the equipments, especially guidance, housed in that vehicle. Acoustic, vibrational, and temperature isolation from new and more stringent levels of excitation were superimposed over reasonably well understood-from POLARIS/POSEIDON experience-shock and pressure environments. In addition, the range extension dictates for weight reduction were complicated by the unique RB placement around the third stage which made thrust termination difficult to engineer.

"GUIDANCE

"An innovative booster energy management scheme (GEM) was coordinated between the missile and guidance design teams. Implementation of a very simple control algorithm relating the missile's velocity change capability to the velocity required vector, through the angle between the two quantities, eliminated the need for thrust termination ports and their associated weights plus greatly reduced guidance computation requirements. Significant weight savings and resultant range gain, with potential for reliability enhancement and cost savings, were the outcome of these design considerations.

"The added time required to attain the higher velocity needed for longer range, because of time/acceleration dependent error sources in the sensors, required changes in design for sensors and gimbals. Computation related software and hardware designs were similarly influenced by these considerations.

"In rounding out the basic needs for the guidance design, the complementing capabilities of the submarine fire control and navigation subsystems were taken into account in devising a budget apportioning error sources to be assigned for all functional elements of the total weapon system.

"Packaged in a four degree of freedom gimbal system, the sensors and their base motion isolation system formed the inertial reference and velocity measurement system (IMU).

"An inflight trajectory sensitive weighting matrix through which computation is made that best estimates corrections to missile position and velocity from star sighting measurements was engineered. Star sighting during missile flight tended to offset the extended time between the surfaced navigation fixes required by the submarine. This was a countermeasure to the anti-submarine warfare (ASW) threat.

"The computational functions and control electronics were engineered into a separate container. The computer was designed to survive and recover automatically from severe transients. The basic logic circuitry was a metallization change to a medium scale integrated array (MSIA) that was fabricated using dielectric isolation rather than junction isolation and on chip thin film rather than diffused resistors.

"The program for the mission was capable of being fixed by the use of a PROM (Programmable Read Only Memory). The fixed constants semi-conductor memory further compressed volume and weight and reduced the internal heat load to be dissipated. One measure of the compression achieved is the fact that 21 modules of MSIA functionally replaced 132 modules as mechanized in the POSEIDON computer which immediately preceded the TRIDENT design. The hardened memory provides for the preservation of critical guidance quantities under environmental stresses and does refresh all flight control critical quantities thus simplifying the flight control functional elements.

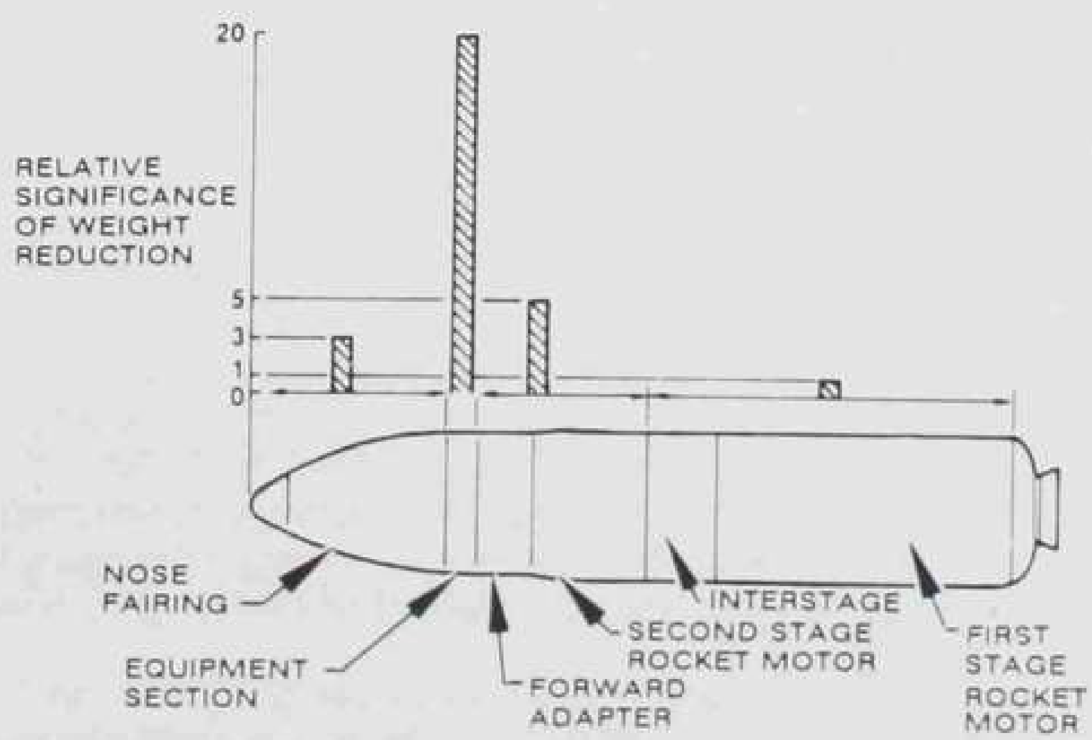
"The production arrangement for TRIDENT guidance hardware is unique to the Submarine Launched Ballistic Missile programs. A single design agent, designated by the Navy performs the development team leadership role. Industrial support contractors, selected competitively, contribute major elements of the design. These elements are integrated by the designated team leader. Subsystems, generally, are prototyped by the design agent with active participation by the industrial support contractors. The center of activity passes, over the life of the program, from the laboratory environment of the design agent, through intensive interactions at the missile team leader's facility and then to the hardware production plant.

"Qualified suppliers compete on annual buys that are based principally on cost to the government. The design agent, coupled with the government's "in plant" quality assurance teams, continually monitor all activity in order to assure product integrity.

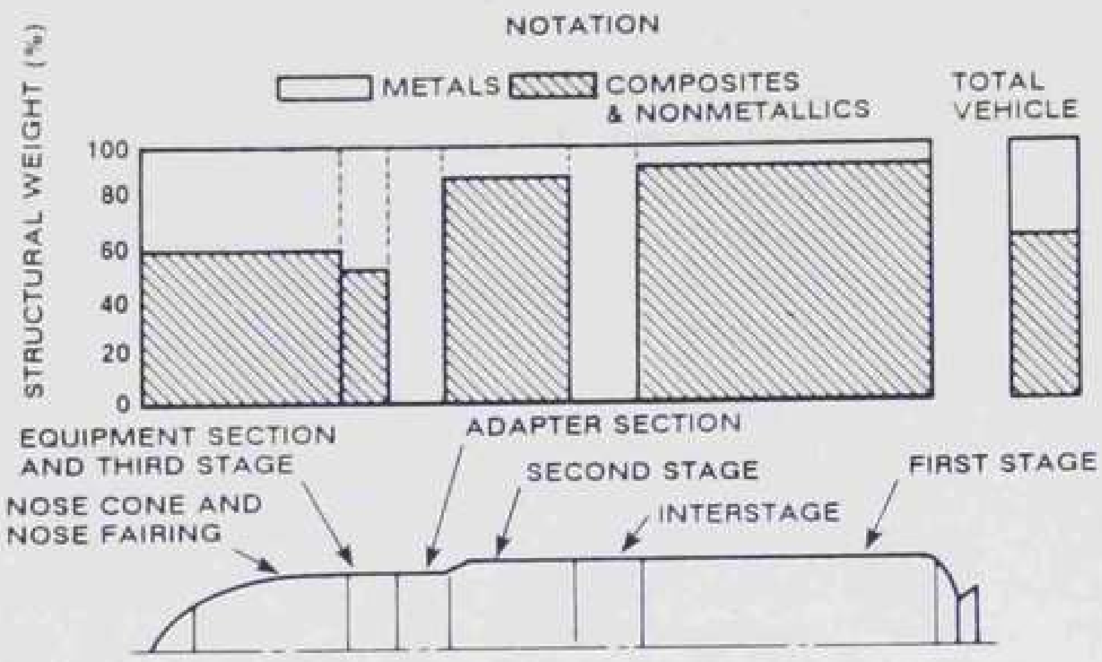
"MISSILE

The first and second stages constitute the major part of the missile structure. The interstage is detached with the first stage and the nose fairing is discarded during second stage burning, after maximum aerodynamic drag, while its weight is still a very small portion of the total weight being accelerated. The post-boost vehicle, or equipment section, is the part of the missile structure in which the greatest range gains can be made by inert weight reduction. This structure carries the guidance, flight control electronics, post-boost propulsion, some power supply, and all the reentry vehicles."

To reduce the ES inert weight, the design utilized graphite-epoxy composite in brackets, third stage (TS) motor support structure and eject cylinder, RB supports, etc. The following figures illustrate the relative significance of weight reduction in the various sections of the missile and their relative contribution as range gainers, and also depict the use of composites in TRIDENT.



Relative Significance of Weight Reduction



Use of Composites in TRIDENT

"The heaviest equipment other than reentry vehicles mounted on the equipment section, was the post-boost control system (PBCS), and hence an important weight reduction target. This system must control the attitude and magnitude and direction of its velocity increments of the post-boost vehicle. Using new high temperature materials and insulation for the valves and manifold permitted weight saving by operating at high gas temperature and pressure and the use of a more energetic propellant.

"The electrical and electronic systems are designed to function reliably in the normal missile environment and must perform during and after being exposed to the neutron and gamma radiation from a nuclear explosion in the general vicinity of the missile as well as the electromagnetic pulse which would result from ionic excitation caused by a high altitude nuclear explosion.

"One of the primary design considerations for electronics was to provide increased capability to control the third stage, interface with an evader reentry system, and provide higher performance control laws while simultaneously reducing weight and volume needs.

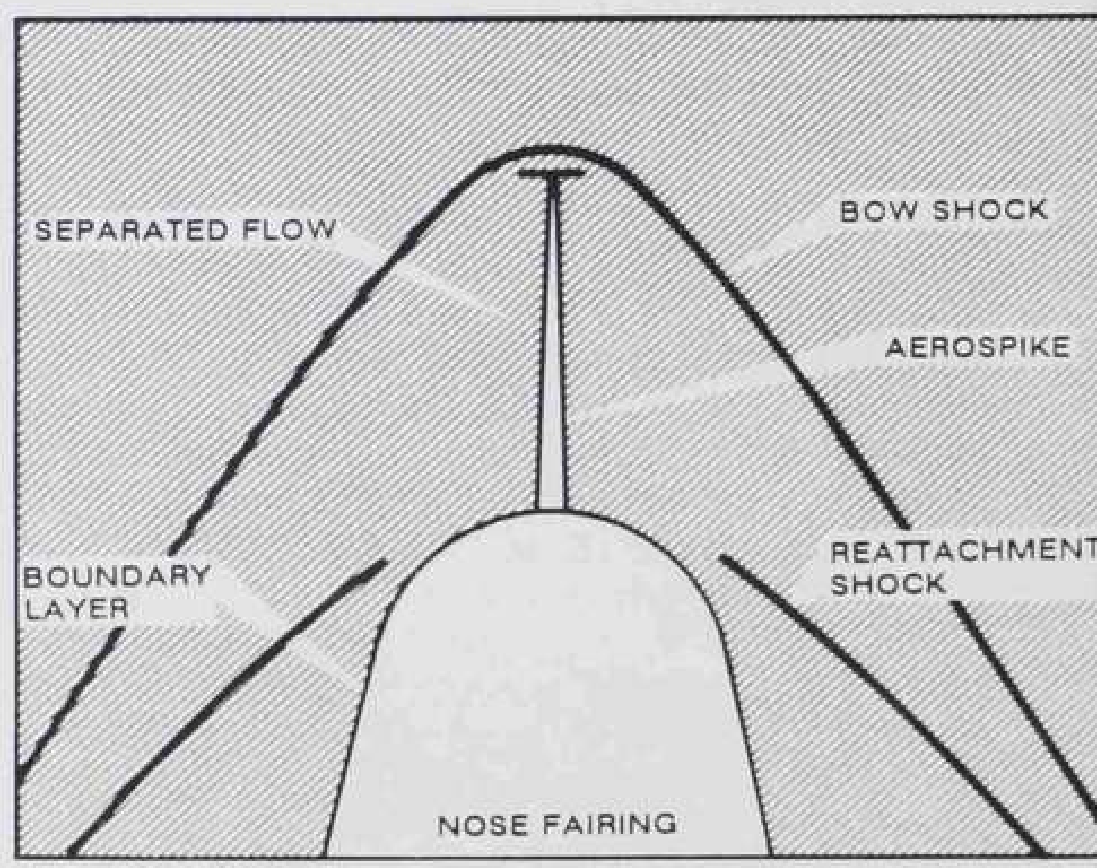
"The requirement to minimize size and weight of packages resulted in selection of the gold beam lead, sealed junction technology for reliability as well as weight and volume reduction, low-power Shottky transistor logic for weight and volume reduction, and dielectric isolation for nuclear hardening for the integrated circuits. This integrated circuit technology was combined with thin film metal hybrid packaging technology for the same considerations of weight, size and reliability.

"Each TRIDENT I missile flight control contains 96 hybrid electronic circuits. A typical hybrid weighs approximately 6 grams with 85 percent of the weight concentrated in the support structure of substrate, leads, cover, and frame. The circuit components and final coating constitute less than 1 gram of the hybrid weight.

"Choice of medium-scale integration (MSI) microelectronic technology influenced the decision to employ a digital flight control electronics package (FCEP). With use of digital MSI devices and a hybrid packaging technology, it was possible to reduce the weight and volume of the FCEP by approximately 50 percent while increasing the capability of the flight control function over that of POSEIDON.

"In addition, a 40 percent weight saving has been realized by the development of plastic in place of aluminum housings for several electronic packages. Protection against the effects of external radiation at radio frequencies and below is achieved by plasma spraying all surfaces with aluminum.

"In introducing a third stage of boost propulsion and making maximum use of the available launch tube volume, the missile nose shape became so much blunter that aerodynamic drag during boost could have significantly detracted from meeting the range increase goal. It therefore became important to reduce boost phase drag. For this purpose, an aerospike was designed to extend from the nose fairing early in flight. The aerospike is self-contained and requires no functional interface input from other missile subsystems. A small solid propellant gas generator provides the energy to extend and lock the aerospike into position. Its ignition is triggered by acceleration of the missile on ejection from the submarine.



Aerospike

"The remaining major technical challenge to achieving the range increase objective was the development of solid propellant rocket motors incorporating technological advancements in both propellants and inert components. In recognition of the importance of, and the difficulties associated with, attaining the performance increment expected from propulsion, exploratory and advanced development efforts were initiated in this area approximately 2 years before the start of engineering development.

"The key element in achieving the range objective was the integration of high energy propellants and the advanced materials into a motor design that delivered the maximum impulse. Operating pressures somewhat higher than those used in prior systems further enhanced performance.

"The high energy propellant selected for all three stages is a cross-linked composite modified double-base formulation. Cross-linking the polymer in the binder by the use of a long-chain diisocyanate permits conventional composite modified double-base propellants to be formulated at an increased solids (fuel and oxidizer) level. The high solid level permits increases in both density and specific impulse.

"Although several subscale and full-scale motors of each stage had been successfully tested during the early development phase, a second stage motor, with propellant known to be well consolidated without porous regions, transited from deflagration to detonation during a static firing in May 1974. DDT of unconsolidated propellant was known to be possible, but this event was apparently unprecedented.

"In the subsequent months, extensive analysis, laboratory experimentation, and large-scale motor tests were conducted to gain an understanding of the mechanism involved. The conclusion reached was that the DDT mechanism involved a high pressure motor case failure, a subsequent dynamic response of the new high modulus fiber case that caused propellant shear failure along the chamber wall and the formation of sufficient surface area to permit pressure run-up to detonation in the confined environment.

"Corrective action taken in the early months following this event was primarily directed toward processing improvements to reduce the likelihood of a pressure excursion and subsequent case failure. The relationship between mechanical properties and shear behavior and flame propagation if shear should occur was unknown and remained to be investigated.

"In June 1975, another second stage motor having suspected defects was static fired in a high hazard test location. After 25 seconds of normal performance, the suspected defects apparently caused rapid pressure increase which again resulted in a high pressure case rupture and transition to detonation. Analysis of the test data clearly indicated that the motor case dynamics would be expected to produce propellant shear.

"After this second event and on the basis of extensive laboratory and subscale testing to identify characteristics critical to detonation, significant changes in first and second stage propellant formulations were made affecting solids loading and binder composition.

"In addition to the reduction in solids level, an increase in the polymer content and a decrease in plasticizer contributed significantly to increase toughness (decreased liability) and damage resistance. Processing changes were also made to improve consolidation and knitting. Chamber and insulator processing improvements that yielded more uniform products were adopted and, in all areas, accept-reject criteria were improved to provide a verified test data base.

"The performance loss associated with the use of less energetic propellants than originally intended increased the need for greater performance contributions by all other areas.

"Missile and propulsion system studies conducted during the engineering development phase indicated that overall system performance would be enhanced by the operation of motors at higher chamber pressures than previously used in strategic systems. Improved case materials would also permit more severe flight and thermodynamic loads, provide sufficient stiffness to limit propellant grain strain at motor ignition, and preclude buckling under stowage and handling loads. To achieve these benefits at minimum weight required a case material with high tensile strength, high modulus of elasticity, and a low density.

"Material tradeoffs and design and processing studies resulted in the selection of Kevlar 49 fiber for all motor cases. Kevlar 49 is an organic fiber with high strength-to-weight and modulus-to-weight ratios. An extensive resin testing program resulted in selection of the epoxy resins to be used in the filament winding process.

"Development of nozzles to survive the high operating pressures and temperatures was also one of the more challenging tasks in the propulsion program. During engineering development, improvements in nozzle technology were pursued in several areas, including:

- Low erosion throat materials
- Lightweight ablative insulation
- Low torque nozzle joints
- Extendible exit cones

"As the program progressed, work in the areas of extendible exit cones, low torque joints, and carbon-carbon exit cones were deemphasized because of reliability, cost, and performance concerns. The selected nozzle design utilizes pyrolytic graphite plates in the throat, carbon-carbon entrance and exit segments and either carbon or graphite cloth phenolic in other areas. An omnidirectional flexible joint enables movement required for thrust vector control.

"Reentry system design objectives included more than doubling the maximum range at which the reentry vehicle with its high ballistic coefficient (weight-to-drag ratio) could reliably withstand reentry heating without significant weight increase. The major technical issues involved in meeting this objective were those of materials technology. Several alternative design concepts for the nosetip, heatshield, and substrate materials were examined in parallel during the early stages of development. A highly successful supplemental flight test program carried out in 1974 and 1975 with surplus Atlas and Minuteman missiles helped in the early selection of materials and design concepts.

"The reentry body has a tape-wrapped carbon phenolic (TWCP) heatshield bonded to a thin-wall aluminum substrate for the shell and a graphite nosetip. The TWCP is similar to material previously used by the Air Force for reentry bodies, but with the carbon particles eliminated. It is made from a carbonized rayon cloth, wrapped on a mandrel, and cured in a female mold. The TWCP ablates during a reentry, leaving at least a minimum amount of cool material intact to impact. The graphite is a fine-grain graphite, especially developed for strong and uniform properties. So critical was graphite quality, and so difficult to inspect the end product, that a separate factory, a computer controlled facility, was built for its exclusive production where processes could be completed controlled.

"Advanced development of a prototype evader reentry system was included in the missile development program to provide reasonable assurance that a possible later decision to initiate engineering development of such a system in response to Soviet ABM deployment would not require reengineering of the weapon system. Flight tests (Mk 500 Program), demonstrated the feasibility of the concept and its compatibility with the TRIDENT missile system.

"In spite of the substantial application of advanced technologies in the necessarily far more complex design of this missile, operational flight test data clearly indicates that TRIDENT is the most reliable as well as the most capable of the five generations of Fleet Ballistic Missiles."

The C4 missile development flight test program commenced on 18 January 1977 with the successful launching of C4X-1 from the flat pad (25C) at Cape Kennedy. This was followed by 17 additional C4X launches from pad 25C. Of these 18 flights, 15 were successful, 1 was a partial success, 1 was a failure and 1 was a no test (due to ground support equipment error). The C4X program completed on 23 January 1979. This was followed by the firing of 7 PEMs (Performance Evaluation Missiles versus Production Evaluation Missiles) from the SSBN-657 during the period 10 April 1979 through 31 July 1979. PEM-1 had a FS motor failure but PEMs 2 through 7 were successful. It was this successful flight test program that lead to SECNAV James Woolsey to comment in January 1980 that TRIDENT I (C4) was "the most successful submarine launched ballistic missile development program to date."

Moreover, the development flight test program was progressing so satisfactorily that after the 12th flight test of the C4X was successfully conducted, Lockheed on 19 May 1978 proposed that the total number of development (C4Xs and PEMs) be reduced from 30 to 25. Following the 16th flight test which was successful, the Director of SSPO determined on 27 November 1978 that the technical objectives of the C4 development program had been met and that the development flights could be reduced from 30 to 25 flight tests (18 C4Xs and 7 PEMs).

Finally on 20 October 1979, the USS Francis Scott Key (SSBN-657), a POSEIDON submarine "backfitted" with TRIDENT I (C4) missiles, deployed for deterrent patrol from Charleston, South Carolina, carrying 16 tactical (4000 nm) TRIDENT I (C4) missiles.

Although the flight test program was progressing satisfactorily, there were problems on the ground.

During static ground firings of rockets motors, there were the two internally-induced detonation mentioned earlier, which resulted in a major effort to resolve and modify the propellant.

During another static ground firing, exercising of the flight termination system resulted in an externally-induced detonation. This resulted in a modification to the flight termination system. That modification, plus the propellant modification, tended to resolve the situation.

Moreover, the sensitivity of the propellant in the FS motor resulted in a modification to the flight trajectory of C4Xs as they flew off Pad 25C. "Jetty Juke" — a "dog leg" early in flight — after liftoff turned directly out to sea followed by a turn downrange to the target area. This "Jetty Juke" (away from the jetting at Cape Canaveral) lessened the possibility of damage due to a possible detonation of the test missile shortly after liftoff.

There were problems in microelectronics. Dielectric Isolation (DI) was a new SOTA technique being designed into the ICs for use in flight controls and interlocks. The various manufacturing vendors had tremendous difficulty in producing acceptable ICs. This coupled with the much-higher design complexity of flight control and interlocks C4 versus C3, led to an unacceptable failure rate during early test of these packages (e.g., 2000 to 3000 percent). Improvements in manufacturing processes, early parts screening, etc., eventually resolved the situation but many interim schedules were impacted. Nevertheless, the scheduled IOC of 1979 was made.

During this 1971 to 1979 time span, some notable FBM things happened.

POSEIDON C3 Blue Ribbon — POSEIDON Modification Program (POMP)

History repeated itself! The POSEIDON C3 OT program began in August 1972. As in the POLARIS A3 program in 1966, the POSEIDON (C3) OT program had results which were significantly different than those of the C3 DASO. The POSEIDON OT program was suspended in March 1973 and again RADM Levering Smith (Director, SPO) on 17 March 1973 convened a special C3 Blue Ribbon Committee (same date as the A3 Blue Ribbon Committee, 17 March — St. Patrick's Day). It was also known as a POSEIDON Reliability Review ($C3R^2$). The co-chairmen of the Blue Ribbon Committee were CDR Charles "Chuck" Gooding, USN, SPO's Deputy Assistant for Weapon System Operation and Evaluation (SP 2050) and Mort Gailey, Lockheed/MSD's Director of Product Support (82-01). The Blue Ribbon Committee findings and recommendations were given to RADM Levering Smith in October 1973 which resulted in implementation of the POMP. The POSEIDON C3 OT program resumed in October 1974 with satisfactory results. It might be noted here that, prior to the initiation of the C3 Blue Ribbon Committee, the Lockheed/MSD POSEIDON Program Office had undertaken, on its own, a System's Checkout, Operations, and Performance Evaluation (SCOPE) program. This effort was folded into the C3 Blue Ribbon Committee after 17 March 1973.

The Blue Ribbon Committee recognized the problems associated with the POSEIDON's SS motor insulation and the POSEIDON's Mk 3 RB nosetip and that Lockheed/MSD had major efforts underway in this area. The efforts of MSD Quality Audit Group (QAG) were also recognized.

The Blue Ribbon Committee findings and recommendations were primarily concentrated on the fact that there was inadequate testing at almost every level: piece part, component, and package.

The "Zero G" phenomena had come into play. The ES of the POSEIDON missile changed orientation (relative to the earth) as it conducted its "bus" operations and RB deployments. Contamination internal to the various electronic boxes was free to float, making various contacts, resulting in electronic anomalies/failures. This free float was the "Zero G" phenomena. Ground testing did not find this contamination, as it was held in place by gravity. The POMP made changes in MSD's inspection and testing policies and procedures. Electronic boxes were subject to extended vibration and shock testing in three axes, temperature cycling, and burn-in. Improvements were made in the failure diagnosis process including feedback/communication to field activities. A "no unverified failure" policy was established. More attention was placed on system testing at the factory and the use of continuous remote monitor during test. The POMP was imposed on all new-built missiles and also to all missiles in the fleet as they were recycled.

QUALITY AUDIT GROUP (QAG)

Apart from scope and the SPO's POSEIDON C3 Blue Ribbon Committee, Lockheed senior management indicated to MSD "(There is)...an obvious indication of potential, serious problems in the POSEIDON program", and directed that a "Special Quality Audit" be conducted by MSD. On 10 May 1973, a QAG was initiated with E. A. Sandor of the Lockheed Propulsion Company as chairman, with Art Hubbard (VP-MSD) as his assistant. Its purpose was to audit the MSD hardware delivered to the POSEIDON Program and the policies and procedures which control its quality.

Although this Lockheed group conducted an independent audit of Lockheed auditing Lockheed, the findings paralleled those uncovered by the customer-oriented group (C3 Blue Ribbon Committee). The findings that directly affected the hardware quality are listed:

a. The policies and practices governing the disposition of packages that fail once but cannot be made to fail again are questionable. The policy states that, after additional investigative testing, if the failure cannot be verified, the package shall receive three successive, successful functional tests and be considered acceptable. This practice allows questionable hardware to be delivered.

b. The number of package failures discovered after factory acceptance tests indicate that the acceptance tests are not sufficiently rigorous to screen out incipient failures.

   The packages do undergo a vibration environment during acceptance test to detect incipient workmanship and component failures. In light of the failure data, this has not been sufficiently effective. Discussions with other programs have indicated other environments such as thermal cycling have been effective in detecting incipient failures.

Failures have also been detected by an added instrumentation system at POMFLANT. (This is not used at Sunnyvale during acceptance testing.) This system is referred to as the Remote Monitoring System.

c. Testing data indicate that some hardware discrepancies are detected during missile system tests and yet all packages, such as spares and those returned for cause, do not receive a system test prior to delivery to the fleet.

d. A review of the parts failure data reveals that parts are subjected to many levels of screening, but many still fail at package or subsequent testing. It was concluded that the most effective means of improvement is to impose increased control and attention to the vendor processes.

e. A review of those failure modes causing flight test anomalies discloses that almost all were discovered in previous ground tests. Corrective action at that time was either not taken or was ineffective.

Other FBM Happenings:

The SECNAV announced the selection of Bangor, Washington, as the initial base for TRIDENT on 16 February 1973.

The President signed the FY 74 Appropriations Authorization Act providing funds for the first TRIDENT submarine on 15 November 1973, and o[n] 25 July 1974 the Navy awarded a fixed-price incen[tive] contract to General Dynamics, Electric Boat Divi[sion], for construction of this first TRIDENT SSBN.

An SFT program (6 flights) to develop a new RB (M[k] 4) for C4 was conducted from 6 March 1974 to 1[illegible] November 1975, along with a Mk 500 maneuverin[g] RB SFT.

The SECNAV on 30 November 1976 announced tha[t] Kings Bay, Georgia, was identified as the preferre[d] alternate site for an East Coast location for FBM submarines (TRIDENT). The site became official on 2[illegible] January 1978. Kings Bay was activated on 2 July 1979 because the treaty with Spain required withdrawal of Submarine Squadron Sixteen from Rota, Spain.

Feeling that the TRIDENT I program was "well in hand," RADM Levering Smith, USN, decided to retire. On 14 November 1977, he was relieved by RADM Robert H. Wertheim, USN, as the Director, SSPO. Upon being relieved of active duty on that date, he was appointed to the rank of Vice Admiral on the retired list, effective 15 November 1977.

It was during this 1971 to 1979 time period that the Navy embarked on a program to extend the time between SSBN overhauls from 7-1/2 years to 10 years. It was the Extended Refit Program (ERP).

The philosophy of the ERP was carried over to provide a SSBN "backfit," converting a SSBN with C3 capability to an SSBN with C4 capability. This allowed for timely completion of an SSBN PEM launch program and an on-time C4 IOC. The program was initially called a "tenderside backfit," but really became a "pier side" backfit at ETR.

EXTENDED REFIT PROGRAM/EXTENDED REFIT PERIOD

In 1974 the SSBN ERP was initiated by the SSPO. Normally, an operational SSBN is scheduled to undergo an overhaul approximately every 7-1/2 years, which resulted in taking it off line for almost 2 years. To increase the SSBNs at sea effectiveness, it was decided to initiate a program to accomplish some preventive/corrective maintenance (mini-overhaul) on SSBNs at its normal refit site. This was done by extending a normal 32-day refit/upkeep between patrols to provide a 60-day extended refit period. This was to be conducted at 4-year and 7-1/2-year intervals after initial deployment or overhaul of a SSBN. The time between overhauls was then extended to 10 years versus the 7-1/2 years.

The ERP is under the cognizance of SP-26 supported by the Naval Sea Systems Command (NAVSEA), weapon system industrial contractors with coordination activity performed by Vitro Corporation, Silver Spring, Maryland. The SSPO technical branches and subsystem contractors conduct two detailed material inspections of each SSBN scheduled for an Extended Refit Period. The ERP-2 inspection, performed approximately 200 days prior to each SSBN's ERP, is the main shipcheck which provides the visibility necessary for tailoring work items to individual hulls. The ERP-1 inspection, conducted approximately 100 days prior to the scheduled ERP, is held at the option of each subsystem technical branch and is for the purpose of gaining updating information where necessary.

Using the information gained from the pre-ERP inspection, the SSPO technical branches prepare and issue detailed documents for each subsystem refit. The subsystem refit plans will provide instructions for

Weapon System material refurbishment or disposition; list tools and test equipment required for subsystem refit; describe any special facilities, tools, jigs, or fixtures required on the tender, including plans for fabrication, if necessary; provide or reference specifications for conduct of FBM Weapon System routines; and contain other data pertinent to the refit.

The SSBN-616/627/640 Class were candidates for the ERP. The first SSBN to undergo ERP was the USS James Madison (SSBN-627); the ERP was conducted at the Holy Loch, Scotland, tender refit site in September - November 1974.

The SSBNs' schedules provided 8 days for normal arrival operations, change of command, off-loads, etc. The SSBN then began ERP when it entered the drydock for 43 days of "shipyard" work followed by 5 days of "dockside" work and plus dock trials for a total of 50 days. This was followed by 10 days of materials and deficiency corrections for a total of 60 days and the end of ERP.

ERP work is performed primarily by the SSPO's weapon system contractors supported as required by SP Technical Branch personnel and ship's force personnel. Based on the inspections conducted during ERP-2 and ERP-1, a Preventive Maintenance Management Plan (PMMP) is prepared prior to the commencement of the ERP. Maintenance/Repair is conducted on the FBM subsystems (launcher, fire control, navigation, test instrumentation, and missile) plus several unique ship subsystems (sonars, ventilation, hovering equipment, etc.).

SSBN-627-640 CLASS TRIDENT I (C4) BACKFIT

As indicated previously, the SECDEF's DCP No. 67 outlined Navy plans for the new ULMS; a long-term modernization plan which proposed a new submarine, a new, longer-range missile (ULMS-II/TRIDENT II — 6000 nm range) and a nearer-term option of an extended-range POSEIDON (ULMS-I/TRIDENT I — 4000 nm range).

Lockheed commenced the TRIDENT I's (C4) OSDP Program in November of 1973 with the missile's IOC date established as 1979. The new submarine, also part of the ULMS plan, was authorized in 1974 but would not be available for IOC in 1979. Thus the Navy decided to borrow a page from the ERP Book. A C3 to C4 SSBN "backfit" program was initiated in mid-1976.

The Navy decided to use the ERP technique (e.g., take a C3 SSBN offline for restricted availability (RAV) and conduct a "tenderside backfit" to a C4 capability).

In early 1978, planning was underway for an initial POSEIDON (C3) to TRIDENT I (C4) SSBN backfit to provide a seagoing launch platform for evaluating, testing and proofing of the C4 PEMs and its associated ship support systems. This evaluation and backfit would allow for timely completion of the C4 missile development flight test program and its IOC in 1979.

This phase was referred to as the PEM SSBN backfit, USS Francis Scott Key (SSBN-657). Following the evaluation of the PEM, selected SSBNs were backfitted and referred to as follow-on backfits. Five additional SSBNs (629, 630, 634, 655, and 658) underwent the "pierside backfit" while six other SSBNs (627, 632, 633, 640, 641, and 643) were backfitted during their normally-scheduled second shipyard overhauls.

The SSPO (SP-26) was the project coordinator for the "pierside backfit" program. He provided liaison with the various SP branches, NAVSEA, Navy field activities, and civilian contractors to coordinate the preparation, logistics, and planning required to execute the production and test phases of the backfits. SP-26 also provided an on-site representative during the execution phase of the "pierside backfits."

All C4 backfit work items were identified in a SSPO TRIDENT I Tenderside Backfit Work Planning document. Reconfiguration of the Weapon System was accomplished by means of Strategic Systems Project Alterations (SPALTs) and Ship Alterations (SHIPALTs). SPALTs and SHIPALTs were provided to the backfit sites as kits, and contained all material, drawings, and installation instructions to accomplish the work.

The POSEIDON (C3) SSBN designated for TRIDENT I (C4) Backfit tied up to Wharf Alpha, POLARIS Missile Facility, Atlantic (POMFLANT) for approximately 10 days to off-load C3 missiles, gas generators, closures, and associated attaching launcher hardware and Mk 3 guidance systems. Following the off-load, the SSBN proceeded to the floating drydock in the Navy Weapon Station (NWS) area on the Cooper River. The TRIDENT I (C4) backfit commenced when the SSBN crossed the sill of the drydock. The Norfolk Naval Shipyard Industrial Team (SYIT) prepared, maintained, and distributed production and test schedules for each backfit. Upon undocking, the SSBN proceeded to NOTU, Cape Canaveral (ETR), to complete the backfit.

NAVSEA provided personnel from the Norfolk Naval Shipyard to form a SYIT which performed the SHIPALTs to the SSBN (e.g., mechanical and piping, electrical/electronic, reballasting, compartment mods). The SSPO's subsystem contractor personnel conducted the SPALTs to components of the Weapon System (e.g., fire control, missile test and readiness equipment (MTRE), launcher tube conversion and ejector group, navigation interfaces). SP-206 provided logistics, facilities, equipment and services support at NOTU, Cape Canaveral, (ETR). There were two 12-hour shifts, 7 days a week for the duration of the backfit.

Final analysis of the Weapon System "backfit" tests was performed by Vitro Corporation, under the direction of SP-20 who had program cognizance and final approval.

Both the PEM-SSBN and the first RAV SSBN to undergo a "tenderside backfit" were scheduled for a 70-day period. The follow-on tenderside-SSBNs were scheduled for a 68-day backfit. The schedules were based on a 7-day, 24-hour work period for the duration of the backfit.

The schedule for the backfits conducted during overhaul was integrated into the overhaul work schedule of the shipyard. For the PEM and the first SSBN "offline RAV" was 1) off-load, 2) commence backfit — 9 days in drydock, 3) transit to ETR — not considered part of the backfit schedule time, 4) 61 days tenderside, for a total of 70 days. The follow-on "tenderside backfit" SSBN had the same schedule except tenderside was reduced to 59 days for a total of 68 days.

The term "tenderside" is a misnomer, since the industrial teams alterations were done "wharfside" at ETR.

The first submarine (SSBN-657) to undergo a "pierside backfit" entered the drydock on 22 September 1978. It remained in drydock until 14 October 1978 and then transited to Cape Canaveral. There the conversion from C3 to C4 was completed 4 December 1978. The SSBN-657 then commenced C4 training, finally conducting a successful launch at ETR of the first TRIDENT I (C4) PEM (PEM-1) on 10 April 1979. Upon completion of the PEM exercise, the SSBN-657 deployed on 20 October 1979 as the first SSBN with TRIDENT I (C4) missiles.

The USS Simon Bolivar (SSBN-641) commenced on 2 March 1979 a scheduled shipyard overhaul-C4 backfit at the Portsmouth Naval Shipyard. This was the first shipyard overhaul to include C4 backfit.

Following the SSBN-657, the SSBN-658 (4 February 1980), the SSBN-655 (16 May 1980), the SSBN-629 (6 September 1980), the SSBN-630 (24 November 1980), and finally the SSBN-634 (18 February 1982) were "tenderside" backfitted and deployed with TRIDENT I (C4) missiles.

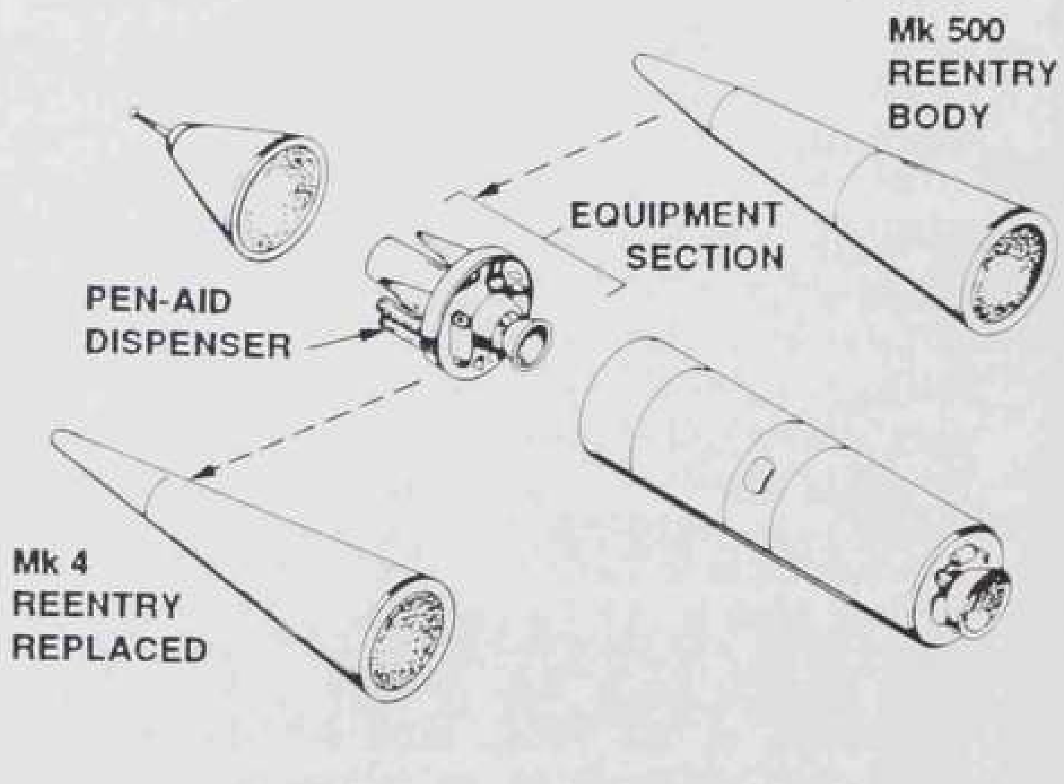
Mk 500 (EVADER) PROGRAM

It was mentioned earlier that the advanced development of a prototype evader reentry system was included in the C4 development program. The RB associated with this system was the Mk 500. Pen-Aids (chaff and decoys) were also associated with this system. A Mk 500 (also called Evader) flight test program was also conducted.

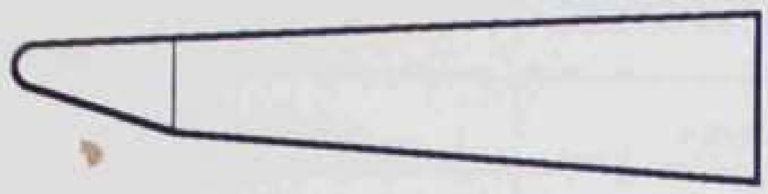
The Mk 500 was a parallel Engineering Development Program (along with Mk 4) but became an Advanced Development Program (ADP) after the ABM Treaty.

The ADP was initiated to provide a "hedge" against potential proliferation or upgrade of Soviet anti-ballistic missile defenses. The program was to develop a small evader maneuvering RB (MaRB) and demonstrate its feasibility and system compatibility with the TRIDENT I (C4) missile system. Upon completion of the ADP, the Mk 500 was to be put in a maintenance status, but to be available for deployment 3 years after go-ahead.

The initial ADP extended from 1971 to 1976. Its objectives were to demonstrate MaRB feasibility; the concept of a fixed trim, moving mass controlled RB; and compatibility with C4. A conical ballistic reentry vehicle was modified to incorporate a fixed-trim asymmetric nosetip and a moving-mass roll control system. Subsequent Mk 500 designs led to a



TRIDENT I (C4) Missile and Payloads



FEATURES
- ASYMMETRICAL SHAPE
- CONTAINS ADDITIONAL SYSTEMS OVER THAT OF CONVENTIONAL BRB
  - ATTITUDE CONTROL
  - GUIDANCE

ADVANTAGE
- IMPROVED PENETRABILITY

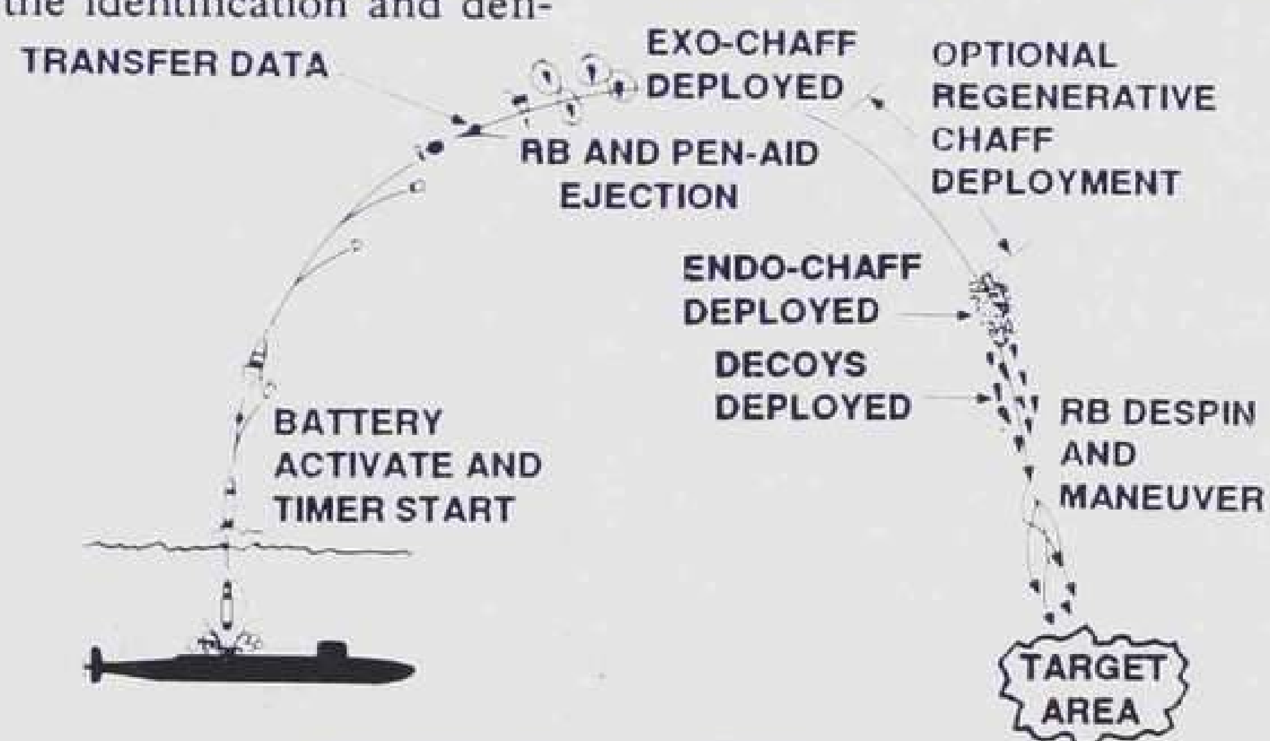
Mk 500

step-trim concept and then to the current variable trim concept with nose canting.

Lockheed had prime system responsibility for the advanced development of the Mk 500 Evader RB, for the establishment and maintenance of TRIDENT I (C4) compatibility with Mk 500 as a candidate optional payload, and for the identification and definition of evolutionary derivatives of the Mk 500 to establish engineering development readiness responsive to the nation's assessment of anti-ballistic missile threat evolution. General Electric, Reentry Systems Division, was the major subcontractor responsible for design of the Mk 500 vehicle and its derivatives, including production of test hardware.

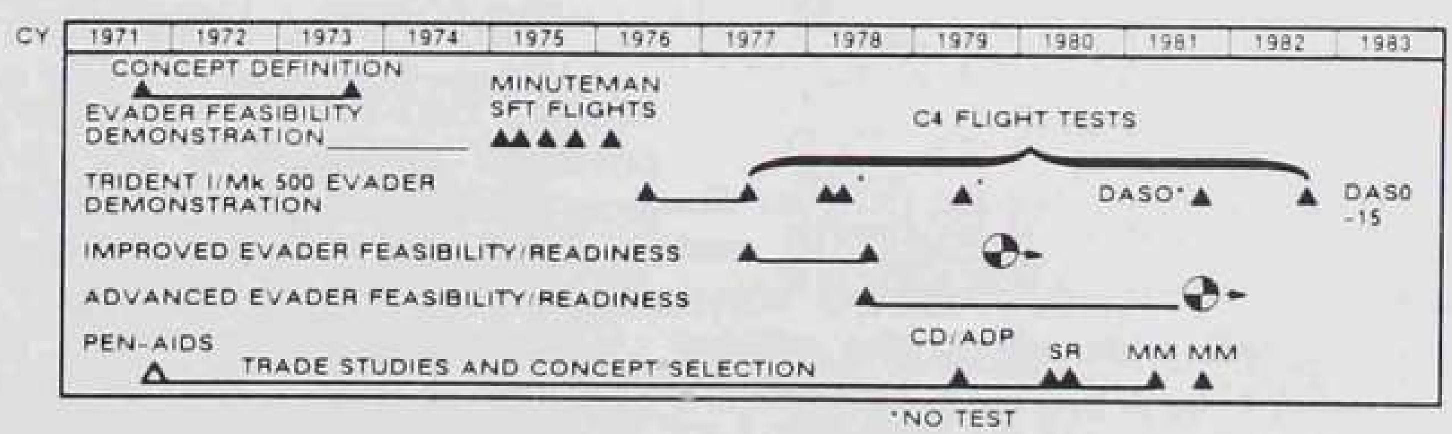
Technical feasibility of the Mk 500 Evader concept has been demonstrated, and gross compatibility of the Mk 500 with the C4 has been proved.

There were five successful flight tests on Minuteman missiles in 1975 and early 1976. This was followed by Improved Evader tests (1976 to 1978) and an Advanced Evader test (1978 to 1982). Compatibility of the original Evader with C4 was successfully demonstrated on C4X-8. The Improved Evader was flown on C4X-13 (success), C4X-14 (no test — missile failure) and PEM-5 (partial success — electronic compatibility anomaly). The Advanced Evader demonstrated capability and C4 compatibility on DASO-8 (no test — missile failure) and DASO-15 (success).



Mk 500 Program History

- DEMONSTRATED FEASIBILITY (7 FLIGHTS)
- DEMONSTRATED COMPATIBILITY (2 FLIGHTS)
- ESTABLISHED WARHEAD INTERFACE
- SELECTED BASELINE PENETRATION AND CONCEPT
- ISSUED ENGINEERING DEVELOPMENT PLAN
- DEMONSTRATED WARHEAD FEASIBILITY (224-80)
- EVALUATED MATERIALS AND PIECE PARTS IN AGT/UGT



Mk 500 Penetration System Sequence of Events

Mk 500 FLIGHT TEST HISTORY

RB	Date	Config	Booster	Major Objectives	Achievement
101	3-6-75	Evader	MM 1	Concept Feasibility	Success
102	5-9-75	Evader	MM 1	Aero/Thermal Performance	Success — System Repeatability Demonstrated
103	8-22-75	Evader	MM 1	Pull down Maneuver, High Loads	Success — Basic Structural Integrity and Trajectory Versatility Affirmed
104	9-10-75	Evader	MM 1	Large Cross-Range High Heating	Success — Continued Confirmation of Basic Design Adequacy
105	1-23-76	Evader	MM 1	Jacket Evaluation Hard Pull down	Success — Jacket Removal Has Minimal Dynamic Impact
207	6-27-77	Evader	C4-X8	Compatibility With C4-X Jacket Demonstration	Success — Major Step in Demonstration of C4 Compatibility
106A	1-17-78	Improved Evader	C4-X13	Improved Evader Demo-Low Altitude	Success — Improved Evader Concept Demonstrated
209	2-14-78	Improved Evader	C4-X14	Improved Evader Demo-Low Altitude DOE Flight Test	No Test — Missile Failure
210	7-14-79	Improved Evader	C4-PEM-5	Compatibility With C4 (Sublaunched)DOE Flight Test ΔV Measurement/Update	Partial Success — EMI Compatibility Problem
211	11-15-81	Advanced Evader	C4-DASO-8	Compatibility With C4 (Sublaunched)DOE Flight Test ΔV Measurement/Update	No Test — First Stage Failure
211A	11-21-82	Advanced Evader	C4-DASO-15	Compatibility With C4 (Sublaunched) DOE Flight Test ΔV Measurement/Update	Success — Compatibility Established AEV Concept Demonstrated

IMPROVED ACCURACY PROGRAM (IAP)

In December 1973, the SECDEF requested that the Navy define a program which could provide significant accuracy improvements in the existing or future submarine-launched ballistic missile weapon systems. The Navy replied that time and effort would be required to understand the error sources in the present systems and to evaluate potential improvements.

NOTE: The following are excerpts or condensations of data from the Improved Accuracy Program Final Report, SSPO Report No. 2200.9B, dated September 1982.

High accuracy had not been a requirement in the development of the POLARIS, POSEIDON, and TRIDENT I SWS; rather, moderate accuracy objectives were established that were within the existing SOTA, and the test instrumentation was designed primarily to quantify the achieved system accuracy. All systems achieved their accuracy objectives.

In March 1974, the SECDEF requested that the Navy submit a program plan for providing an early-1980s option for major accuracy improvements in the TRIDENT I or a follow-on system.

That program (IAP) was to identify and establish a means of significantly reducing the error sources and to pursue advanced development in selected areas pertinent to improving accuracy. Incorporation of the accuracy improvements in deployed SWSs was not, however, a directed goal of the IAP.

On 10 April 1974, Lockheed was authorized to perform Improved Accuracy Studies under separate provisions of the TRIDENT I (C4) OSDP contract. Studies included initial planning of a program to define the capability to measure accuracy error sources and to identify accuracy improvements to current and future FBM systems. The IAP began with an authorization of FY 1975 funds and was completed in FY 1982.

The IAP was undertaken with an overall objective of establishing a technical basis for providing an early 1980s option for major accuracy improvements to the TRIDENT I or a follow-on submarine-launched ballistic missile weapon system. The overall objective was divided into three specific objectives.

The first of these objectives was to obtain an understanding of the sources of inaccuracy by:

a. Developing high-fidelity analytical models for predicting the accuracy of the TRIDENT I SWS and of improved submarine-launched ballistic missile weapon systems.

b. Determining, with high confidence, the accuracy of the TRIDENT I SWS in both tested and untested conditions.

c. Understanding the causes of bias in the observed impacts of the POSEIDON SWS.

d. Developing instrumentation for the precise measurement of TRIDENT I SWS error contributors.

The second objective was to initiate design and advanced development of those critical SWS subsystem components whose error sources must be made smaller to substantially reduce the circular error probability (CEP) of future submarine-launched ballistic missiles. This would be done by:

a. Assessing and, where feasible, demonstrating improvements in TRIDENT I components known to be significant error contributors.

b. Identifying advanced concepts that might be more effective in improving TRIDENT I accuracy, and by assessing the technical feasibility of incorporating such advanced concepts into operational hardware or procedures.

c. Determining the technical feasibility of the advanced instrumentation required to support the development of an improved accuracy submarine-launched ballistic missile weapon system.

The third objective was to provide the bases for determining, with confidence, the costs and schedules associated with quantified accuracy improvements.

The IAP was concurrent with the TRIDENT I development program and the POSEIDON follow-on operational test program. The IAP objectives were incorporated, on a synergistic basis, into these ongoing programs.

In pursuing these objectives, the IAP activities were divided into two categories: 1) accuracy understanding and 2) accuracy improvement.

Accuracy Understanding

In large part, obtaining any accuracy improvement in a future submarine launched ballistic missile weapon system necessitates understanding the limitations of the present systems. Further, because the design of a future weapon system would probably be based on evolutionary growth from present systems, each significant error contributor in the present system had to be thoroughly understood so that potential changes could be evaluated as suitable improvements for incorporation into a future improved system. To accomplish this, the accuracy understanding activities were divided into model formulation, model verification, and development of instrumentation and data processing techniques.

The degree of confidence placed on the understanding of current submarine launched ballistic missile accuracy, and the confidence in postulating accuracy improvements of a future system, are a function of the quality of the models employed. To ensure adequate quality, the models were verified to the extent and detail appropriate or, in many cases, practicable. Verification (i.e., determination of how well the models can emulate actual performance) took many forms. Maximum use was made of the ongoing TRIDENT I development, DASO, and OT programs to acquire previously-unrecorded data. Unique test programs were also designed to observe and quantify previously-unrecorded phenomena.

Data gathered from the ongoing POSEIDON weapon system demonstration flight-test program indicated that, while the accuracy was within the goal, there was an impact bias. Because many elements of the POSEIDON SWS are common with TRIDENT I and may be incorporated into an advanced system, an objective of the model verification activity was resolution of this bias by determining its cause(s), or ensuring that a similar bias was not present in the TRIDENT I SWS.

Previous submarine-launched ballistic missile programs were not structured to collect the detailed and precise data required to fully understand the causes of miss and to verify the error models used to describe system accuracy. To overcome this limitation for the IAP, a significant instrumentation and data processing activity was inaugurated for use in conjunction with TRIDENT flight test programs. (See C4X Flight Test Summary for IAP flights.) Existing capabilities were upgraded and improved instrumentation to measure previously unrecorded phenomena was developed. In addition, new data processing techniques were developed to extract the maximum information from the data gathered.

The Satellite Missile Tracking System (SATRACK) was a major instrumentation component developed as part of the IAP for the flight test program. It was basically a transponder carried in the test missile's ES which received location signals from Global Positioning System (GPS) satellites and transmitted them to the launch area and downrange support ships. Comparison between the satellite signals provide the location of the missile's ES in space. Useful SATRACK measurements were provided on the last three C4X flat-pad flights, and later on the PEMs, 5 DASOs, and 15 OTs.

Accuracy Improvement

In parallel with the accuracy understanding activities, a comprehensive effort was directed toward identifying all concepts that offered accuracy improvement potential. Those candidates were evaluated, through a series of iterative steps, for their suitability for incorporation into our operational weapon system.

These efforts were divided into two parallel phases, those devoted to subsystem improvements and those concerned with weapon system synthesis and analysis.

In the first phase, candidate concepts for accuracy improvement were drawn from broad categories that included:

a. Improvements in procedures and software.

b. Improvements in hardware that were functionally equivalent to existing TRIDENT I SWS hardware but represented tighter tolerances or a new approach.

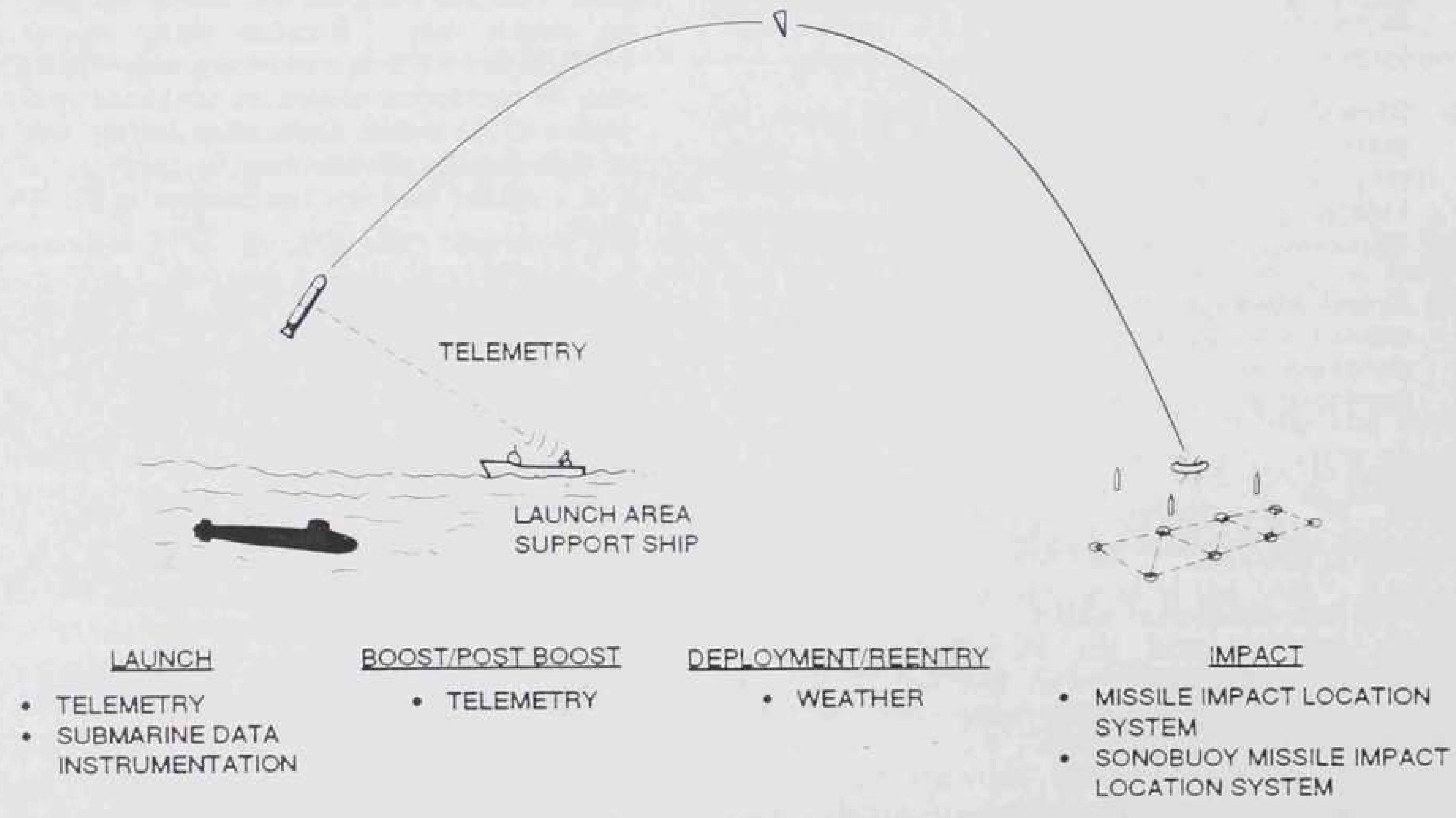
c. Advanced components and concepts based on sensing phenomena or parameters not measured or measured differently in the TRIDENT I SWS.

Initially, improvements were evaluated in a subsystem context for accuracy potential only, and later, to a limited extent, for other subsystem attributes (e.g., development risk, cost, schedule, and reliability). From this evaluation emerged a list of subsystem options that were sufficiently viable for further consideration in a system context.

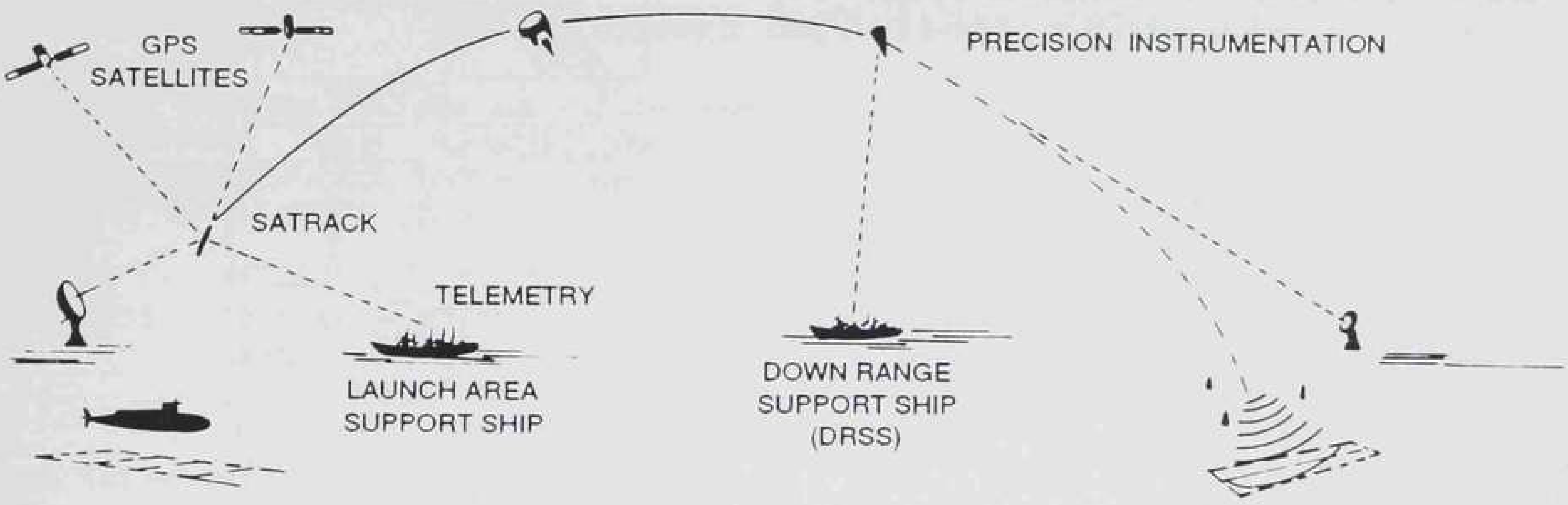
During the second phase, subsystem improvements were periodically synthesized into discrete weapon system configurations and evaluated in a system context primarily for accuracy sensitivity to operational and environmental conditions.

Other evaluations included subsystem compatibility, personnel requirements, system cost and schedules, vulnerability, and ship security.

Also included in the accuracy improvement activity was the effort relating to advanced flight-test instrumentation and data processing necessary to ensure timely identification of anomalies during the development program and to provide confident verification of the achieved tactical accuracy.



Instrumentation Used in a Normal Flight Test Program



PRE LAUNCH/LAUNCH
- LORAN NAVIGATION SYSTEM
- VELOCITY AND POSITION RECORDING SYSTEM
- TELEMETRY
- SUBMARINE DATA INSTRUMENTATION

BOOST/POST-BOOST
- SATRACK
- RADAR
- TELEMETRY

DEPLOYMENT/REENTRY
- PRECISION INSTRUMENTATION PACKAGE (PIP) IN REENTRY BODY
- RADAR
- OPTICS
- WEATHER

IMPACT
- MISSILE IMPACT LOCATION SYSTEM
- SONOBUOY MISSILE IMPACT LOCATION SYSTEM

Improved Accuracy Program Instrumentation

The TRIDENT I (C4X) flat-pad launches were primarily missile and guidance development flights. During these development flights, the accuracy models for the weapon were being improved. For 13 of 18 C4X flat-pad flights, the known accuracy disturbance effects could be removed analytically from the miss data. Eight of the later flat-pad flights had suitable powered-flight phase trajectory position and velocity coverage from radar and telemetry measurement system. The last three flights had useful SATRACK (trajectory position and velocity employing satellites) coverage. Extrapolations provided good agreement between computed misses and actual miss measurements. During the period of these flights, laboratory tests and analysis identified additional correctable error model terms in the guidance system. Also during these flights, experiments associated with variations in the RB deployment system were carried out. The associated precision instrumentation package (PIP) identified and confirmed significant improvements to the average RB release velocity impulse value.

At the outset of the C4 PEM operations in April 1979, the first testing of the integrated TRIDENT I weapon system in an operational environment began. A weapon system accuracy model had been formulated based on the best subsystem models that could be devised with data from ground and flat-pad cumulative development flight tests. The first cumulative system-level verification analysis of the accuracy model using the TRIDENT I SWS flight-test data was completed in December 1980, based on a test sample size of 26 missiles, consisting of 6 PEMs, 5 DASOs, and 15 OTs.

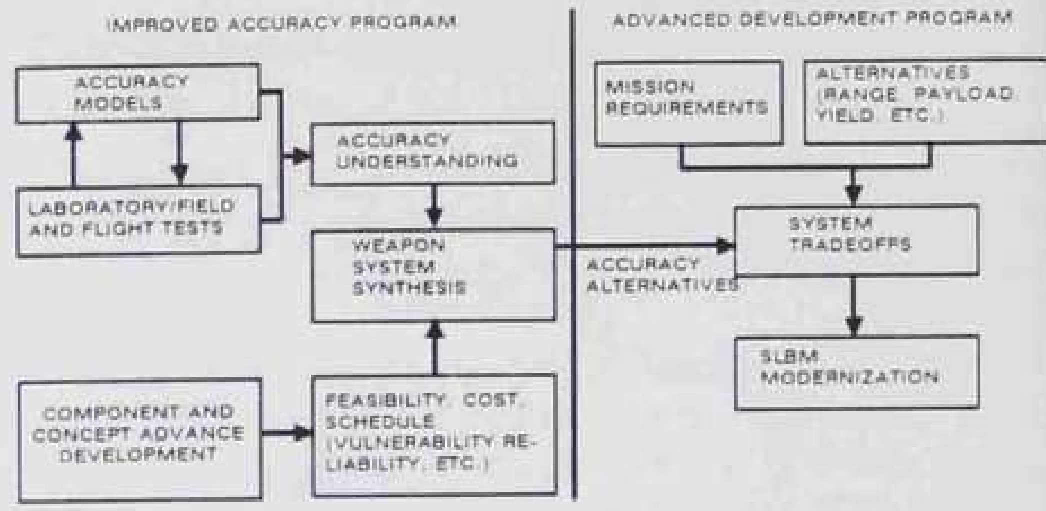
Findings from the initial verification analysis resulted in major revisions to both the weapon system and instrumentation system models. With respect to the weapon system model, the principal outcome was that demonstrated accuracy was considerably better than predicted.

Subsequently, significant changes were made in the navigation, guidance, and deployment models, and revised or new bias predictions were included in areas of fire control software and gravity and geodetics. Improvements were also made to the SATRACK and LONARS (LORAN navigation receiving system) measurement models. In particular, a LONARS position reference bias found during SATRACK consistency checks was corrected through resurvey of the LORAN-C network in the DASO operating area.

In parallel with the effort to understand the sources of error in existing submarine-launched ballistic missile systems, a program was conducted to evaluate methods of improving accuracy for a future system.

A wide variety of accuracy improvement alternatives was considered. These included competing technologies and, in some instances, competing suppliers of component hardware. The evaluations included analytical studies, as well as the results of laboratory and at-sea testing.

The most promising concepts were combined or synthesized into weapon system configurations for system-level performance assessments. Concurrent with the latter stages of the system synthesis activity, a submarine-launched ballistic missile force modernization program (TRIDENT II, D5) was initiated. This led to the recommendation of an initial baseline for incorporation into an advanced, highly-accurate weapon system.



Accuracy Improvements — IAP ADP

HIGHLIGHTS (MID-1971 - 1979)

Some of the following highlights are extracts from SSPO's document "FBM Facts/Chronology — POLARIS, POSEIDON, Trident" and from Lockheed's "Fleet Ballistic Missile Systems Program History".

10 May 1971 — The initial POSEIDON C3 patrol was successfully completed with the arrival of the USS James Madison (SSBN-627) alongside the tender Canopus (AS-34) at Holy Loch, Scotland, for a refit period.

4 Nov 1971 — The Blue Crew of the USS Nathanael Greene (SSBN-636) successfully launched a POSEIDON C3 missile in support of the ship's DASOs. This was the first surface launch of a POSEIDON missile from an SSBN.

15 Nov 1971 — A level-of-effort contract to conduct tasks related to upgrading the range and penetrability characteristics of the POSEIDON missile system was awarded. The objective of this effort was to reduce the technical risks in any ADP considered in the future.

1 Apr 1972 — The exchange program to replace all POLARIS A3P missiles in the Pacific Fleet with A3T missiles was completed.

16 May 1972 — With the return of the USS John C. Calhoun (SSBN-630) from POSEIDON patrol at Holy Loch, Scotland, a total of 1,000 POLARIS/POSEIDON deterrent patrols had been successfully completed (975 POLARIS/25 POSEIDON).

16 May 1972 — The SECDEF approved the proposal by the SECNAV to rename the ULMS program as the TRIDENT program.

29 Sep 1972 — The FBM weapon system test ship, the USS Observation Island (EAG-154), was decommissioned. The ship had supported various FBM missions since 1958.

2 Oct 1972 — A contract to develop the C4 missile system was executed. This was a continuation of the effort that began under the contract to upgrade the POSEIDON missile system.

14 Dec 1972 — The President approved TRIDENT for inclusion in BRICKBAT priority of the Master Urgency List. This is the highest industrial priority for defense projects.

16 Feb 1973 — The SECNAV announced selection of Bangor, Washington, as the initial base for TRIDENT operations.

17 Mar 1973 — RADM Smith (SP-00) convened a special POSEIDON/C3 Blue Ribbon Committee to evaluate the differences between the POSEIDON C3 DASO performances and that of the C3 OT program. This Blue Ribbon Committee was also known as the C3R², and was convened on the same day as the prior A3 Blue Ribbon Committee (e.g., 17 March 1966, St. Patrick's Day). C3 OT operations were suspended in March 1973. The Blue Ribbon Committee findings resulted in the POMP. OT operations were resumed in October 1974.

10 May 1973 — Lockheed senior management instructed MSD to establish (independent of the C3 Blue Ribbon Committee) a QAG to audit MSD's hardware delivered to the POSEIDON Program. E. A. Sandor, Lockheed Propulsion Company, was the chairman, with Art Hubbard (VP-MSD) as his assistant. The QAG findings paralleled those uncovered by the Navy's C3 Blue Ribbon Committee. The POMP corrected these deficiencies.

10 Aug 1973 — The US POLARIS (A3) missile was phased out in the Atlantic when the USS Robert E. Lee (SSBN-601) transferred to the Pacific Fleet.

15 Nov 1973 — The President signed the FY 74 Appropriation Authorization Act providing funds for the first TRIDENT submarine.

6 Mar 1974 — The first flight in support of the C4 Mk 4 Supplemental Flight Test Program was conducted from Vandenberg Air Force Base. This was the first of six planned flights.

9 Jun 1974 — The USS John Marshall (SSBN-611) completed her final POLARIS (A2) deterrent patrol prior to overhaul. With the completion of MARSHALL's final patrol, all of the eight POLARIS (A2) missile-carrying submarines were off-line for overhaul and conversion, and the A2 missile was phased out of operational use.

25 Jul 1974 — The Navy awarded a fixed-price incentive contract to General Dynamics, Electric Boat Division, for the construction of the first TRIDENT submarine. The contract included an option for construction of three additional TRIDENT submarines.

19 Aug 1974 — OSDP contract awarded to Lockheed for TRIDENT I missile system development plus the production of 52 missiles, including RB shells. The contract provided for support equipment and technical services to outfit and support operation of TRIDENT I and backfit submarines, SWFPAC, POMFLANT, and training facilities.

9 Nov 1974 — The first SSBN ERP was completed at the Holy Loch tender refit site on the USS James Madison (SSBN-627). The extended SSBN upkeep concept, a 60-day period, spaced at 4 and 7 1/2 years, allowed accomplishment of preventive/corrective maintenance not possible during a normal 32-day upkeep.

Year End 1974 — The last two of the 627/640-class SSBNs completed conversion and were deployed with C3 missiles, making a total of 22 C3 SSBNs, plus 8 with A3T missiles. The designation of POMFPAC was changed to SWFPAC.

28 Feb 1975 — The Navy exercised the contract option for construction of the second and third TRIDENT submarines.

1975 — The first SFT of the advanced development Mk 500 Evader RB was conducted from Vandenberg Air Force Base, using a Minute Man Booster. This was the first of five planned tests.

5 Jun 1975 — Several studies were underway in the SSPO. A restudy of an FBM contingency site for the Rota Squadron was directed by the CNO. The SSPO was designated as lead activity for site evaluation, NAVFAC as lead for site preparation, and CINCLANTFLT as lead for relocation and activity planning.

13 Nov 1975 — The sixth and final C4 Mk 4 SFT (SFT-06) was conducted from Vandenberg Air Force Base.

Year End 1975 — The first of the 616-class SSBNs to be converted to C3 deployed in June for a total of 23 C3 SSBNs. The remainder of the class was either in or awaiting conversion, or in predeployment at the end of the year. Two additional 608-class SSBNs deployed with A3T/A3TA missiles for a total of 8 A3T/A3TA SSBNs in the Pacific. The remaining 2 candidates were still in overhaul. During 1975, a change in reentry system configuration was accomplished in the deployed C3 SSBNs.

23 Jan 1976 — The fifth SFT (SFT 105) of the Mk 500 Evader RB was conducted from Vandenberg Air Force Base.

10 Apr 1976 — Keel-laying ceremony for lead TRIDENT submarine, the USS Ohio (SSBN-726), was held at General Dynamics, Electric Boat Division, Groton, Connecticut. Mrs. Robert Taft, Jr., wife of Senator Taft (R. Ohio) was the sponsor.

15 Apr 1976 — POSEIDON (C3) conversion of the USS John Adams (SSBN-620), the last ship in the FY 1974 conversion program, was completed at Portsmouth Naval Shipyard.

30 Nov 1976 — The SECNAV announced that Kings Bay, Georgia, had been identified for further study as the preferred alternative location for the possible construction of an East Coast refit site for Navy FBM submarines.

Year End 1976 — The final two 608-class SSBNs deployed with A3T/A3TA missiles on completion of their second overhaul period, for a total of 10 A3 SSBNs in the Pacific. Five 616-class SSBNs completed conversion and deployed with C3 missiles. This brought to 27 the total of C3 SSBNs deployed in the Atlantic.

14 Nov 1977 — RADM Levering Smith, USN, was relieved by RADM Robert H. Wertheim, USN, as the Director, SSPO. Upon being relieved of active duty on that date, he was appointed to the rank of Vice Admiral on the retired list, effective 15 November 1977.

Year End 1977 — Thirty of the planned 31 SSBNs completed conversion to C3. The SSBN-626 remained to complete conversion. There were nine consecutive successful test flights, commencing with C4X-1 on 18 January 1977 and closing out the year with C4X-12 on 5 December 1977.

26 Jan 1978 — The SECNAV announced that Kings Bay, Georgia, would be the site of the new Submarine Support Base.

12 Apr 1978 — The 12th flight test in the TRIDENT (C4) development program (C4X-15) was successfully conducted from flat pad 25C at Cape Canaveral, Florida. A joint Navy/Air Force recovery team retrieved the expended FS motor for use in a motor insulator evaluation program.

19 May 1978 — LMSC proposed that the number of TRIDENT I (C4) development flight tests be reduced from 30 to 25.

13 Jul 1978 — The expended SS motor from TRIDENT I (C4) development flight test, C4X-12, which was conducted on 5 December 1977, was found washed up on the shore of a small island in the Bahamas. The motor was recovered and returned to the vendor for inspection.

22 Sep 1978 — The USS Francis Scott Key (SSBN-657) entered drydock at the FBM Support Site IV, Charleston, South Carolina, to begin the industrial phase of the TRIDENT I (C4) backfit program. The ship was to remain in drydock until 14 October 1978 and then transit to Cape Canaveral, Florida, for the remainder of the industrial phase.

24 Oct 1978 — Assembly of the first TRIDENT I (C4) PEM commenced at POMFLANT. A flight test program consisting of the launch of seven PEM missiles from the USS Francis Scott Key (SSBN-756) was to be conducted to demonstrate weapon system capability, performance, and compatibility, and that tactical missile production units, subjected to the underwater launch environments, achieved the design performance demonstrated during flat pad testing.

27 Nov 1978 — Following an extensive evaluation, the Director, SSPO, determined that the technical objectives of the TRIDENT I (C4) development program had been met and that the development flight tests could be reduced from 30 to 25 flight tests.

4 Dec 1978 — The industrial phase of the conversion of the USS Francis Scott Key (SSBN-657) from POSEIDON (C3) to TRIDENT I (C4) missile capability at Cape Canaveral, Florida, was completed 9 days ahead of schedule. Early achievement of this milestone was attributed to the teamwork of the many government and contractor organizations involved.

Year End 1978 — SSBNs 600 and 602 shifted their base of operations from Guam to Pearl Harbor in November. Sixteen C3 OT/FOT and 2 C3 DASO missiles were expended during the year. The last of the 31 SSBNs to be converted to C3 configuration (SSBN-626) was completed.

The POMP was completed in June.

23 Jan 1979 — The 18th and final flight test in the TRIDENT I (C4) development program (C4X-21) was successfully conducted from a flat pad at Cape Canaveral, Florida.

25 Jan 1979 — The first TRIDENT I (C4) PEM (PEM-1) completed assembly at POMFLANT. The first production missile body (P-1) was completed and shipped from LMSC to POMFLANT on 29 January 1979.

2 Mar 1979 — The USS Simon Bolivar (SSBN-641) commenced a scheduled 16-month overhaul C4 backfit at the Portsmouth Naval Shipyard.

This was the first shipyard overhaul to include C4 backfit.

4 Apr 1979 — As part of the U.K. Chevaline (A3TK) program, a missile was successfully launched from a flat pad at the Eastern Test Range, Cape Canaveral, Florida.

7 Apr 1979 — The USS Ohio (SSBN-726), the first TRIDENT submarine, was launched at General Dynamics Corporation, Electric Boat Division.

10 Apr 1979 — The Navy's (first) TRIDENT I (C4) PEM was successfully launched from the submerged submarine, the USS Francis Scott Key (SSBN-657), off the coast of Florida near Cape Canaveral. The purpose of the PEM-1 flight test was to demonstrate the submerged launch capability of the TRIDENT SWS in a backfitted POSEIDON submarine. However the FS motor failed early in flight, after ignition.

8 Jun 1979 — The USS Mariano G. Vallejo (SSBN-658), departed for patrol following completion of the last SSBN upkeep at Rota, Spain. FBM tender USS Canopus (AS-34) departed Rota on 10 June 1979 for Site IV (Charleston, South Carolina) and relieved the USS Simon Lake (AS-33), which was to proceed to the Kings Bay, Georgia, refit site.

2 Jul 1979 — The FBM tender refit site at Kings Bay, Georgia, was activated. The need for this new site arose because the Treaty of Friendship and Cooperation with Spain required withdrawal of Submarine Squadron Sixteen from Rota, Spain, by 1 July 1979.

FBM tender USS Simon Lake (AS-33) arrived at Kings Bay, Georgia, to provide POSEIDON (C3) and TRIDENT I (C4) tender service.

30/31 Jul 1979 — The Navy's sixth and seventh TRIDENT I (C4) PEMs were successfully launched from the submerged submarine, the USS Francis Scott Key (SSBN-657).

28 Aug 1979 — The Blue Crew of the USS Francis Scott Key (SSBN-657) successfully launched the first TRIDENT I (C4) production missile to be flight tested during the ship's DASO.

15 Oct 1979 — On behalf of the SECNAV, ADM A. J. Whittle, CNM, presented the Navy Unit Commendation Award to the SSPO. The Director, RADM R. H. Wertheim, USN, accepted on behalf of the SSPO.

The award was presented in recognition of exceptionally meritorious service by personnel of the SSPO and participating field activities in the prosecution of the TRIDENT I (C4) development program from October 1973 to October 1979.

16 Oct 1979 — A consolidated FY 80 CPIF/CPFF production and processing contract (P&PC) was awarded to LMSC. The contract award was for approximately one half of a billion dollars and was the first contract of this type awarded by the SSPO. The contract contained completion-type tasks for the production of TRIDENT I (C4) missiles as well as annual tasks, such as processing of the C3/C4 missiles at the POMFPAC and A3/C4 missiles at SWFPAC

20 Oct 1979 — The USS Francis Scott Key (SSBN-657), the first POSEIDON SSBN configured with TRIDENT I (C4) missile capability, deployed for deterrent patrol from Charleston, South Carolina, carrying 16 tactical TRIDENT I (C4) missiles.

9 Nov 1979 — Fiscal year 1980 FPI multiple incentive contracts between the SSPO, Singer-Kearfott Division, and General Electric for TRIDENT I (C4) Mk 5 guidance systems were executed. As far as was known, these were the first contracts ever awarded using equal quantity, performance sensitive, competitive procurement concept. The performance incentive features were structured to operate independently on the contract ceiling price.

10 Dec 1979 — The USS Francis Scott Key (SSBN-657), the first POSEIDON

SSBN configured with TRIDENT I (C4) missile capability, completed her initial C4 deterrent patrol.

Year End 1979 The USS Theodore Roosevelt (SSBN-600) and the USS Abraham Lincoln (SSBN-602) terminated their strategic role in November.

The final C4X flight test was successfully conducted at the Air Force Eastern Test Range in January, and with seven PEM exercises conducted from USS Francis Scott Key (SSBN 657) from April through July, the C4 Development Flight Test Program was completed.

TRIDENT C4X FLIGHT TEST SUMMARY

C4X GENERAL CHARACTERISTICS

To achieve the desired 4000 nm range, the Trident I (C4) became a three-stage solid-propellant missile with basically the same envelope dimension as a C3 (e.g., 34.1 ft in length and 74 in. in diameter). There was a weight increase to approximately 73,000 lb. There was an increase in the C4's NF envelope, compared to C3, to allow introduction of a solid-propellant TS booster in the center of the ES/NF.

Each of the three stages has a boost rocket motor with advanced propellants, improved case materials, and a single lightweight movable nozzle with a TVC system of lightweight gas-hydraulic design.

Boost velocity control is achieved by burning all boost propulsion stages to burnout, shaping the trajectory to use all the energy, without thrust termination. This method is termed generalized energy management steering (GEMS). The ES is powered by a solid-propellant PBCS.

Miniaturizing and repackaging missile electronic components also contributed to reduced package sizes, weights, and calibration, thereby allowing more volume for propulsion.

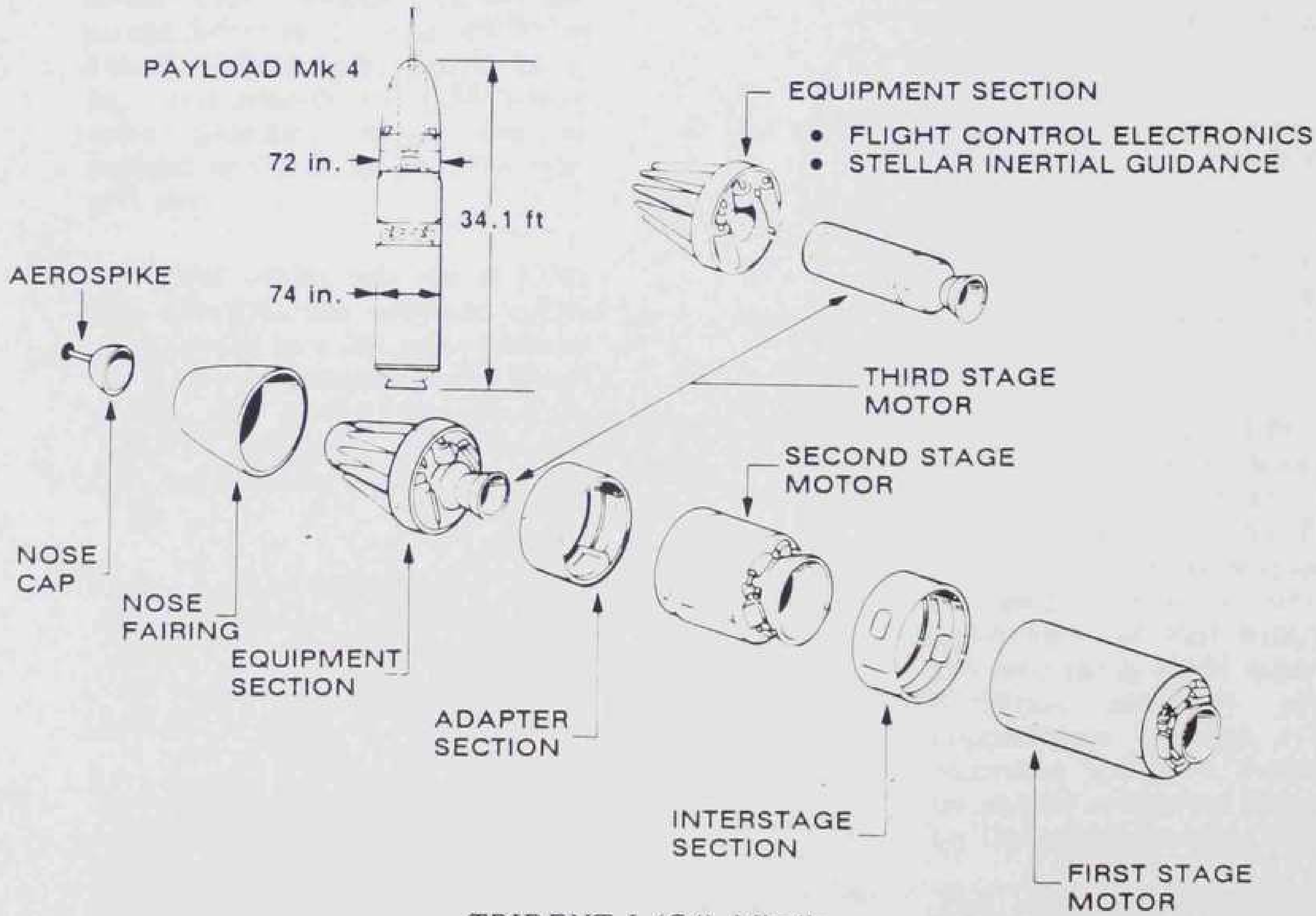
In the missile electronics, particularly in the flight control electronics package and instrumentation, three micro-electron technologies existing as separate entities were brought together into a single electronic device. These were beam lead, dielectric isolation, and low-power Shottky transistor-transistor logic.

Improved propulsion performance was achieved by advancing propellant and materials technologies, including high-energy propellants, chamber materials, and lightweight low-erosion nozzles.

Improved system accuracy was achieved by incorporating a stellar-inertial guidance concept, by improving the Navigation and Fire Control systems, and by more accurate control of RB separation.

Inert weights were reduced with structures fabricated from composite graphite-epoxy materials which represent 40 percent weight saving compared to similar structures made from aluminum. A concentrated effort to reduce the Mk 4 RB weight as much as possible was also conducted.

A deployable aerospike, extended shortly after launch, was incorporated to reduce the frontal drag of the C4 NF by approximately 50 percent. This unique feature, utilized for the first time on a ballistic missile, was adopted to offset the aerodynamic drag and performance degradation of the unusually blunt NF selected to accommodate the payload and the TS rocket motor.



TRIDENT I (C4) Missile

TRIDENT C4X FLIGHT TEST SUMMARY

Flight No.	Vehicle No.	Launch Date	Launch Facility	Major Objectives	Remarks
1	C4X-1	1-18-77	AFETR-25C	FD, MR, SP	Success
2	C4X-2	2-15-77	AFETR-25C	FD, MR, SP	Success
3	C4X-3	3-28-77	AFETR-25C	FD, MR, SP	Success
	C4X-4			*	
	C4X-5			**	
4	C4X-6	4-29-77	AFETR-25C	SCF, FD, MR, SP	Success
5	C4X-7			**	
6	C4X-8	6-27-77	AFETR-25C	SCF, FD, MR, SP	Success
7	C4X-9	9-03-77	AFETR-25C	SCF, FD, MR, SP	Success
8	C4X-11	10-19-77	AFETR-25C	SCF, FD, IAP, SP	Success
9	C4X-12	12-05-77	AFETR-25C	SCF, FD, SP	Success
10	C4X-13	1-17-78	AFETR-25C	SCF, FD, SP	Success
11	C4X-14	2-14-78	AFETR-25C	SCF, FD, SP, IAP	Failure
12	C4X-15	4-12-78	AFETR-25C	SCF, FD, SP, IAP	Success
13	C4X-17	6-22-78	AFETR-25C	TR, FD, SP, IAP	Partial Success
14	C4X-18	8-10-78	AFETR-25C	TR, FD, SP, IAP	Success
15	C4X-16	10-26-78	AFETR-25C	TR, FD, SP, IAP	Success
16	C4X-19	11-17-78	AFETR-25C	TR, FD, SP, IAP	Success
17	C4X-20	12-16-78	AFETR-25C	TR, FD, SP, IAP	No Test
18	C4X-21	1-23-79	AFETR-25C	TR, FD, SP, IAP	Success
19	PEM-1	4-10-79	SSBN 657	TR, FD, SP, IAP	Failure
20	PEM-2	6-8-79	SSBN 657	TR, FD, SP, IAP	Success
21	PEM-3	6-19-79	SSBN 657	TR, FD, SP, IAP	Success
22	PEM-4	7-14-79	SSBN 657	TR, FD, SP, IAP	Success
23	PEM-5	7-22-79	SSBN 657	TR, FD, SP, IAP	Success
24	PEM-7	7-30-79	SSBN 657	TR, FD, SP, IAP	Success
25	PEM-6	7-31-79	SSBN 657	TR, FD, SP, IAP	Success

LEGEND

FD — Flight Dynamics
MR — Material Response
SP — Subsystem Performance
SCF — System Concept Feasibility
IAP — Improved Accuracy Program
TR — Tactical "Test Missile" Readiness

*C4X flight test cancelled. C4X-4 hardware used for free-flight test (FFT) program.
**C4X-5 and C4X-7 flight tests cancelled due to a propulsion test anomaly. Replaced by C4X-21.

THE NEW GENERATION (1980 – 1989)

The STRAT-X study in 1967 recognized that the submarine-launched ballistic missile system was one of the more survivable legs in the Triad strategic nuclear deterrent system. However, it also recognized that the system would need upgrading due to eventual aging of the submarine, improving Soviet ASW capability, and a need for an enlarged submarine operating area (e.g., longer range). The Navy (SSPO) had commenced studies of a new Undersea Long-range Missile System (ULMS). All of this resulted in the Deputy SECDEF approving a Decision Coordinating Paper (DCP) No. 67 on 14 September 1971 for the ULMS.

The ULMS Program was a long-term modernization plan which called for a new, larger submarine and a new, longer-range missile while preserving a nearer-term option to develop an extended-range POSEIDON missile.

In December 1971, the Deputy SECDEF PBD authorized an accelerated ULMS schedule with a projected deployment of the new SSBN and missiles in 1978. In May 1972, the term "TRIDENT" replaced "ULMS," the name "TRIDENT II" was used to designate the ultimate longer-range missile, and the Navy Program Objectives Memorandum (POM) submission outlined funding for the TRIDENT II (D5) program based on a 1984 IOC. Later on 3 August, the SECDEF in a Program Decision Memorandum (PDM) advanced the D5 IOC 2 years to FY 1982. So it began — oscillating D5 IOC dates and associated impacts to the TRIDENT I (C4) development program schedule.

The Navy appealed that date, requesting a FY 1983 IOC but, on November 1972, the SECDEF decision stood, an IOC of FY 1982. This was again reiterated in October 1973.

Also on 18 October 1973, a TRIDENT I DSARC (Defense Systems Acquisition Review Council) II and an overall TRIDENT program review was conducted. On 14 March 1974, the Deputy SECDEF issued two requirements. The first requirement was parallel (to C4 development) advanced development effort for major accuracy improvement in the C4 and follow-on missiles (beginning of the IAP). The second requirement was for follow-on alternatives to the C4 missile, or a new D5 missile, or a variant of C4 with larger FS motor.

The SSPO responded to this second requirement in May 1974 with a brief report grouping candidate missile alternatives into three basic categories: (1) C4 alternatives, 74 in. missiles with varying degrees of C4 commonality; (2) various "stepped" D5 missile alternatives with an 82 in. FS and 74 in. upper stages that were similar to C4; and (3) D5 alternatives which were all-new, 82 in. missiles.

An abnormal rate of inflation in 1974, plus future increases projected for 1975 – 76, resulted in a SECDEF directed IOC slip of the TRIDENT II to CY 1983.

This was followed by a SECDEF decision in January 1975 to a further slip to FY 1985 due to budgetary problems.

On 10 February 1975, the SECDEF issued a study directive for examining feasible degrees of the Air Force's Missile X (MX)-TRIDENT II commonality, potential performance degradations, and resultant cost advantages associated with the various degrees of commonality. A first draft was due for review on 1 June 1975, with the final draft due on 1 July 1975. It was also during this time frame that the TRIDENT II Characteristics Study was underway. The Navy's perception of the specific military requirement for TRIDENT II were in a state of flux. Hard-target capability appeared to be in the SECDEF's mind but no firm nuclear weapons employment policy appeared. In fact, none was likely until MX commonality and possible improved accuracy alternatives were resolved. In line with this, the SECDEF, on 23 July 1975, deferred TRIDENT II operational availability date (OAD) to 1987.

On 3 May 1976, the Deputy SECDEF wrote to the SECNAV, outlining the desirability of SWS having both survivability and a wide range of capability. The TRIDENT submarine, having invulnerability as well as the potential for increased throwweight, "encourages consideration of options to expand our SLBM capability against the full spectrum of the target system." The Navy was therefore requested to develop an overall TRIDENT II missile development plan for increasing the "utility" of the FBM system for IOC in the 1980s.

In the meantime, in 1976 Congress, for the second consecutive year, denied the Navy's request for research, development, test, and evaluation (RDT&E) funding to initiate TRIDENT II conceptual development.

On 16 August 1976, when the SECNAV responded to the Deputy SECDEF above-mentioned guidance — outlining TRIDENT II conceptual goals for an all new D5 hard-target system — he noted that only minimal in-house effort could be undertaken in FY 1977. But assuming that TRIDENT II funding would be available in FY 1978, it still appeared feasible to plan for a 1987 IOC. Meeting such a schedule, however, would definitely be contingent upon DoD waiver of normal acquisition procedures. The SSPO's position was that, without relief from the regulations of the Office of Management and Budget (OMB), DoD, SECNAV, Office of the CNO, and CNM procurement, an IOC in the 1980's was impossible. On 17 January 1977, the Deputy SECDEF reaffirmed the waivers that had been previously granted for C4 (16 July 1973) and approved the proposed TRIDENT II program for proceeding on an urgent basis to meet a 1987 IOC.

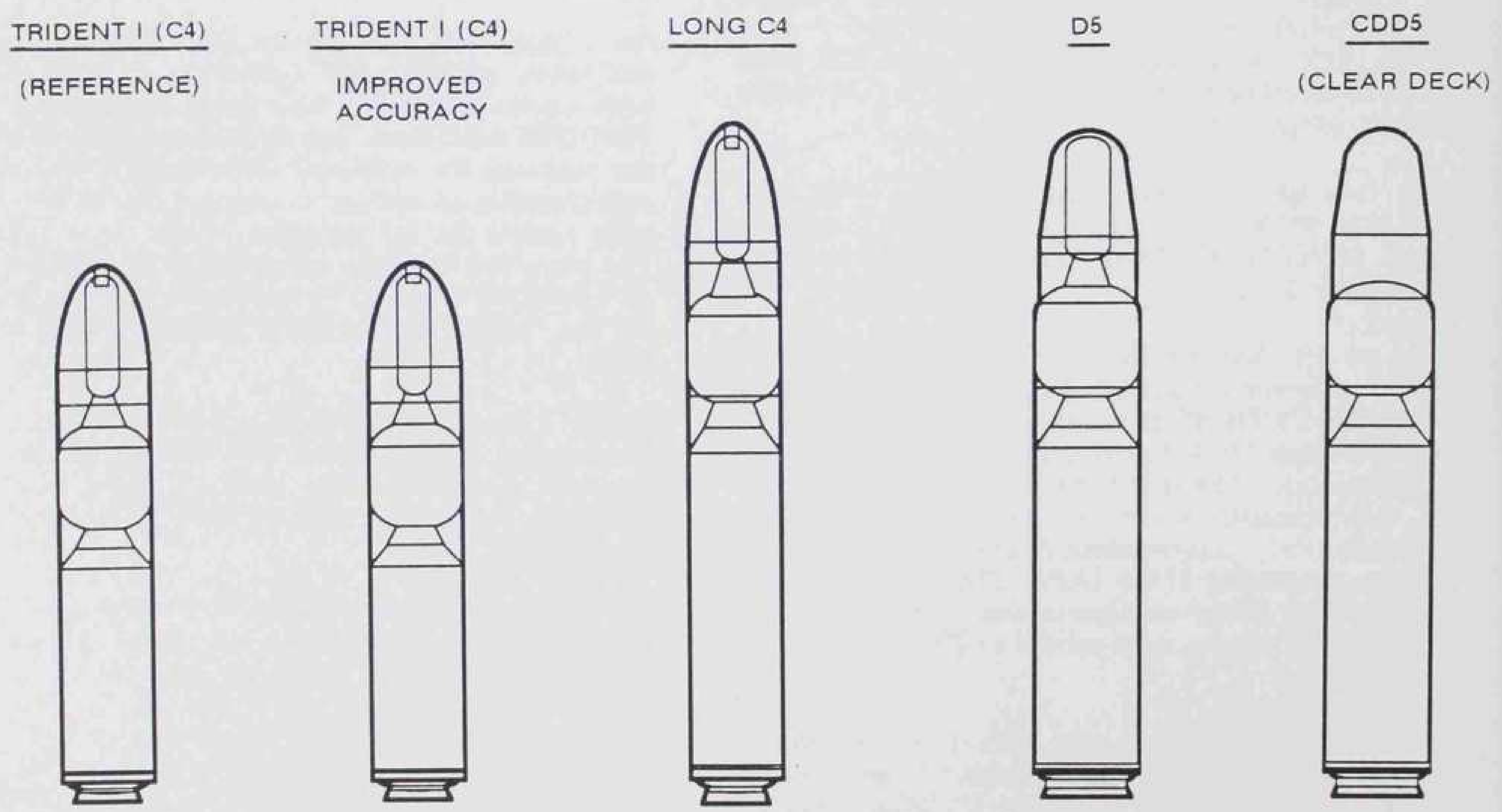
In addition to the Deputy SECDEF waivers, the SSPO later sought and obtained an explicit determination from the Assistant SECNAV (I&L) (25 March 1977) that TRIDENT II represented an evolutionary growth within the TRIDENT system as called for in DCP No. 67, was not subject to competitive exploration of alternative system design concepts, and was exempted from rules for the avoidance of organizational conflict of interest.

On 23 December 1976, the Deputy CNO directed the SSPO to proceed with conceptual development using available resources pending appropriation of RDT&E funding. The operational capabilities specified were to include hard-target capability, flexible payload options, and alternate payload capability.

Congress, in the FY 1978 budget, granted $5 million to conduct basic design and tradeoff studies.

The SSPO awarded concept study contracts to the FBM development team in early FY 1978 with the initial task to provide preliminary performance characteristics, development schedules, and rough-order-of-magnitude (ROM) budgetary estimates for a matrix of missile and reentry body (RB) options. Missile options were constrained to sizes defined in earlier (1974) studies, with a maximum diameter of 82 in. and a maximum length of 42 ft 1 in. Missiles studied included an accuracy upgrade to C4, a long C4, an all-new larger three-stage missile with architecture similar to C4, and an all-new clear-deck design. RB options included the Mk 4, the Mk 500, the Mk 12A, and new ballistic and maneuvering RBs derived from on-going advanced ballistic reentry systems (ABRES) studies. Configuration studies and the estimated performance, together with ROM cost and schedule information, was the basis of data provided for use in testimony to Congress in April 1978 (for FY 1979 budget).

The Navy/SSPO's concept study plans were altered at almost the same time in order to respond to an Under Secretary of Defense, Research and Engineering (USD,RE) memo of 21 April 1978. This memo directed the Air Force and Navy to undertake a joint 90-day study to define a common missile to satisfy both MX and TRIDENT II requirements and constraints and, as a variant to this common missile, to



Missile Options

define a mostly-common missile wherein the more-expensive elements of the missile would remain common, but unique subsystems could be added to utilize the larger missile sizes usable in the MX weapon system. Development schedules, costs, and risks were also to be defined, and a plan was to be formulated for management of the development and acquisition of the common and mostly-common missiles.

A TRIDENT II baseline was defined as a point of departure for the study. Although uncorroborated by detailed study, the probable target missile that could be accommodated in the TRIDENT submarine (83 in. diameter and 44 ft length) was established in order to provide maximum performance in the MX application. This baseline TRIDENT II, with a modification to the guidance system, additional electronics hardening, and the addition of an external protective coating for dust and debris protection, was determined to be the common missile. It satisfied the Navy TRIDENT II requirements established for this study but did not satisfy Air Force payload requirements. The mostly-common missile was a variant to this common missile where, for Air Force application, a unique propulsion stage was used between the common FS and SS to configure a longer three-stage missile with increased range/payload performance. It was estimated that 6 to 6-1/2 years would be required to develop these missiles after an initial year of detailed program, requirements, and interface definition. The management plan recommended that a single service, either the Air Force or the Navy, should be responsible for development and acquisition of the common or mostly-common missiles. Each service would continue to be responsible for development and acquisition of its unique weapon system elements.

In September 1978, the studies were extended to another variation of commonality wherein two boost propulsion motors would be common for use as TRIDENT II FS and SS, and as MX FS and TS.

Prospects for the TRIDENT II program were not improved when Congress appropriated only $5 million of the requested $15 million requested for FY 1979. The SECDEF showed a 1990 IOC of the program was funded at a decremented level.

By December 1978, it was the consensus of the Navy, Air Force, and USD,RE that the relatively-small cost advantage (estimated $300 million Navy savings in 1979 dollars) would not offset the risks and disadvantages of a common missile. SSPO internal planning guidance was for a stand-alone TRIDENT II, IOC FY 1990.

Thus, the Navy felt free to proceed with TRIDENT II, whatever it might be, and that was the problem. Congress felt there was no clearly-delineated requirement for TRIDENT II. Budget was not forthcoming. Congressional conferences on appropriations provided only minimal budgets. In addition, the SECDEF and the Navy positions on types of effort and level of funding fluctuated. In fact, the Navy was instructed in November 1979 to pursue a program of incremental submarine-launched ballistic missile modernization, citing the Presidential decision for full MX development and the difficulty of funding more than one program at a time. A TRIDENT I (C4) Weapon System Accuracy Upgrade with an IOC of 1988 was considered.

In March 1980, the SECDEF, in his budget submittal to Congress for FY 1981, proposed a significantly-increased level of funding for a 3-year ADP for submarine-launched ballistic missile modernization. The principle emphasis was accuracy improvement applicable to an upgraded C4, a long C4, or an all-new D5 missile which would fill the TRIDENT SSBN launch tube envelope and be capable of increased range, payload, as well as accuracy. A DSARC review was to be conducted at the end of FY 1983 to select a modernization option for an IOC not later than CY 1989. The rationale for submarine-launched ballistic missile modernization provided was:

1. Enhance SSBN survivability by increasing range
2. Minimize total weapon system costs by increasing payload
3. Balance the Triad by adding hard-target kill capability through improved accuracy
4. Enhance essential equivalence through increased warhead inventory, throwweight, and accuracy
5. Provide Strategic Arms Limitation Treaty (SALT) negotiating flexibility by having the most-effective submarine-launched ballistic missile that could be deployed in the TRIDENT submarine.

As to the issue of affordability, the proposed DoD budget requested $36 million for FY 1981 and reprogramming from other sources of $61 million which would provide $97 million for the first year of ADP.

The House Armed Services Committee (HASC) recommended no funding, but the Senate Armed Services Committee (SASC) recommended a full $97 million. However, the SASC asked for a plan to be provided which incorporates "the fullest possible competition... (and) should consider competing among contractors for each major component, including the integrated missile." If the plan were to reveal that competition of such major components was not in the best interests of the U.S., then a justification should be supplied. Finally, $65 million was appropriated for submarine-launched ballistic missile modernization, and the Navy was directed to reprogram the necessary amount to conduct an RDT&E ADP. It was not until March 1981 that reprogramming of the additional $32.897 million was undertaken. Thus, the SSPO pursued its first year of the ADP at decremented funding levels.

On 2 February 1981, the SECDEF forwarded to the SECNAV his Secretary of Defense Decision Memorandum (SDDM), documenting the decision to proceed into Phase I (Demonstration and Validation) of the submarine-launched ballistic missile modernization program. The SDDM reiterated previous SECDEF rulings that a follow-on to TRIDENT I would be an evolutionary development within the existing system.

On 6 March 1981, as requested by the SASC, the DoD forwarded the Navy's submarine-launched ballistic missile Modernization Acquisition Plan to the Committees on Armed Services. The SECDEF, in his letter of transmittal, again endorsed an acquisition approach consonant with the evolutionary nature of the submarine-launched ballistic missile program and DoD policy on the issue since 1977. Essential to the plan would be retention of the proven SSPO management structure and the existing Navy/contractor subsystem management teams, with maximum competition at the subcontract level. Since accuracy improvement was a major and challenging objective of the program, use of the existing contractor team, which had participated in the IAP since 1974, was considered the most-efficient approach. Since any modernization option under consideration would have extensive commonality with its predecessors, it must be compatible with existing basing and logistic support systems. Competition at the prime contractor level would result in a duplication of efforts and facilities, a significant increase in program costs, and a delay of the proposed system IOC by approximately 2 years.

The ADP, from the beginning, considered C4 upgrades and a new D5 missile. In June 1981, the USD,RE wrote the SECDEF that a decision should be made and that it should be a new TRIDENT II (D5). On 2 October 1981, President Reagan made an address which called for modernization of the strategic forces. The Deputy SECDEF immediately directed the Navy to fund development of the D5 missile with a December 1989 IOC. On 26 October, the SSPO stated that all effort on C4 upgrades (C4U) and a long C4 (C4L) would be discontinued. The planned TRIDENT I missile inventory would be reduced from 969 to 630, and all RDT&E effort would be directed toward "a new development, advanced technology, high accuracy D5 system."

In the SECDEF FY 1981 DoD budget submittal to Congress in March 1980, the TRIDENT II IOC was December 1989. Reflecting interests of some members of the Armed Services Committee, the CNO in October 1981 asked the SSPO "what if" for a 1-year acceleration of IOC. This was followed in January 1982 for a "what if" for a 2-year acceleration.

On 1 June 1982, the SECDEF wrote to the Armed Services and Appropriations Committees that, based on Navy studies, he had decided not to accelerate the TRIDENT II program, instead, retaining the 1989 IOC. The system would be introduced into the fleet at a slightly-increased rate. The decision was based on performance penalties resulting from acceleration and the requirements for increased near-term funding. Initially, the Navy planned to introduce D5 by backfitting it into the 12th TRIDENT submarine constructed for the C4 system. The restructured plan would introduce the new system with the ninth new construction hull, obviating the need for backfitting four boats, increasing the rate of deployment, and resulting in a cost avoidance of $680 million (FY 1983 dollars).

By 11 March 1982, agreement had been reached between the U.K. and the U.S. to purchase the TRIDENT II missile system. On 20 September 1982, the SSPO was designated the U.S. Project Officer under the terms of the sales agreement. In addition, the responsibility for managing U.S. government activities relative to the sale were delegated to the SSPO by the SECNAV.

The procurement of D5's replaced the U.K.'s original request of 10 July 1980 to procure C4's.

In keeping with the objective of effectiveness against the entire target spectrum, Deputy SECDEF Frank Carlucci advised the SECNAV in December 1982 to include funding for a new RB/warhead combination for TRIDENT II. The new RB designated Mk 5, was to have a higher yield than the Mk 4, thus increasing the weapon system's effectiveness against hard targets.

Finally, the Deputy SECDEF on 28 October 1983 authorized the Navy to proceed to Full Scale Engineering Development (FSED) of the TRIDENT II (D5) SWS and initiate production to meet a December 1989 IOC.

Thus, the third and final phase of the Navy's ULMS program long-term modernization plan was underway. The ULMS program, as outlined in the Deputy SECDEF DCP No. 67 of 17 September 1971 called for a new, longer-range missile and a new, larger submarine while preserving a nearer-term option for an extended-range submarine-launched ballistic missile. The nearer-term option was achieved with the deployment on 20 October 1979 of TRIDENT I (C4) missiles on the USS Francis Scott Key (SSBN-657), a backfit submarine. The new, larger submarine, USS Ohio (SSBN-726), deployed on 1 October 1983 with C4's. Now FSED of the new longer-range missile was underway.

The TRIDENT II Weapon System was to be an evolution of the TRIDENT I. However, going back to be an advanced technology missile capable of 4000 nm range when carrying a similar payload as the POSEIDON (C3) would carry to approximately 2000 nm. It was also constrained to fit in the submarine's circular cylinder launch tube which contained the C3. Thus, the new C4 missile could be used in then-existing submarines (e.g., approximately 74 in. in diameter and close to 34 ft in length). In addition, the accuracy of the new C4 missile system was to be equivalent at 4000 nm to that of the POSEIDON C3 at 2000 nm. To satisfy this range requirement, a TS boost propulsion stage was added to C4 to increase range along with propellant improvements and reduction in inert missile weights. Developments in the guidance system was the major contributor to maintaining accuracy.

Now that the new bigger TRIDENT submarine (Figures E-1 through E-4) was available for the TRIDENT II (D5), the additional space could be considered in the missile design. Moreover, with the possibility of a bigger and associated improved performance, a larger payload could be incorporated. Using the concepts from the IAP, improvements could be developed for the subsystems of the weapon system to provide the desired improved accuracy, all leading to hard-target capability.

Thus, with the larger submarine, the TRIDENT II (D5) Weapon System became an evolution of the TRIDENT I (C4) system with technology improvements in all subsystems of the weapon system: missile (guidance and reentry system), fire control, navigation, launcher and test instrumentation (non-tactical) subsystems, resulting in a missile with additional range, improved accuracy, and heavier payload.

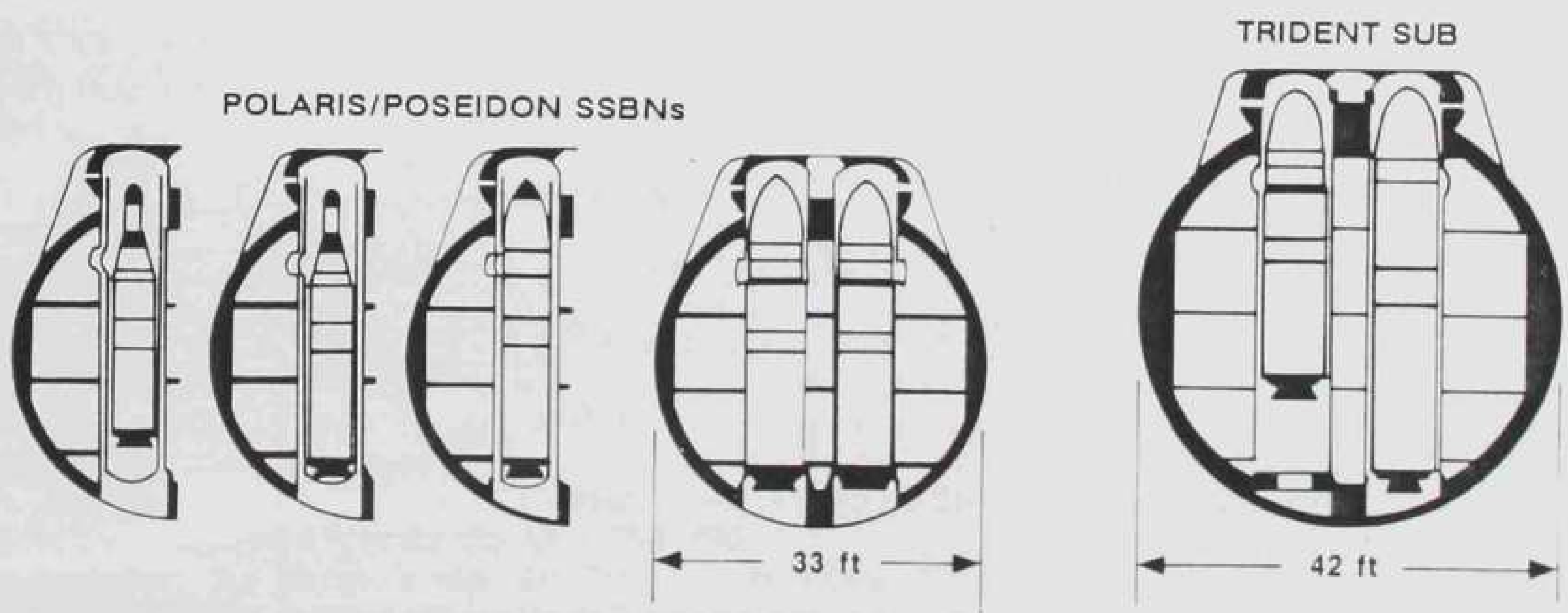
THE TRIDENT SUBMARINE

SSBN-726 class FBM submarines can carry 24 ballistic missiles with MIRV warheads that can be accurately delivered to selected targets from almost anywhere in the world's oceans. Earlier FBM ships carry 16 missiles.

A cylindrical pressure hull structure of HY-80 steel is supported by circular frames and enclosed by hemispherical heads at both ends. The pressure hull provides an enclosure large enough for weapons, crew, and equipment with enough strength to enable the ship to operate deep enough to avoid easy detection.

A streamlined (fish-shaped) outer hull permits the ship to move quietly through the water at high speeds. This outer hull surrounds the forward and aft end of the pressure hull and is not built to withstand deep submergence pressure. It is normally considered as the main ballast tanks.

The superstructure is any part of the ship that is above the pressure hull. This would include the sail or fairwater area, and the area above the missile tubes.



	A1	A2	A3	C3	C4	C4	D5
DATE DEPLOYED	1960	1962	1964	1971	1979	1979	1989
RANGE (nm)	1200	1500	2500	2500	4000	4000	>4000
LENGTH (ft)	28.5	31.0	32.3	34.1		34.1	44.6
DIAMETER (in.)	54	54	54	74		74	83
WEIGHT (lb)	28,000	32,500	35,700	64,000/73,000		73,000	~130,000

Fig. E-1 FBM Constraints and Growth

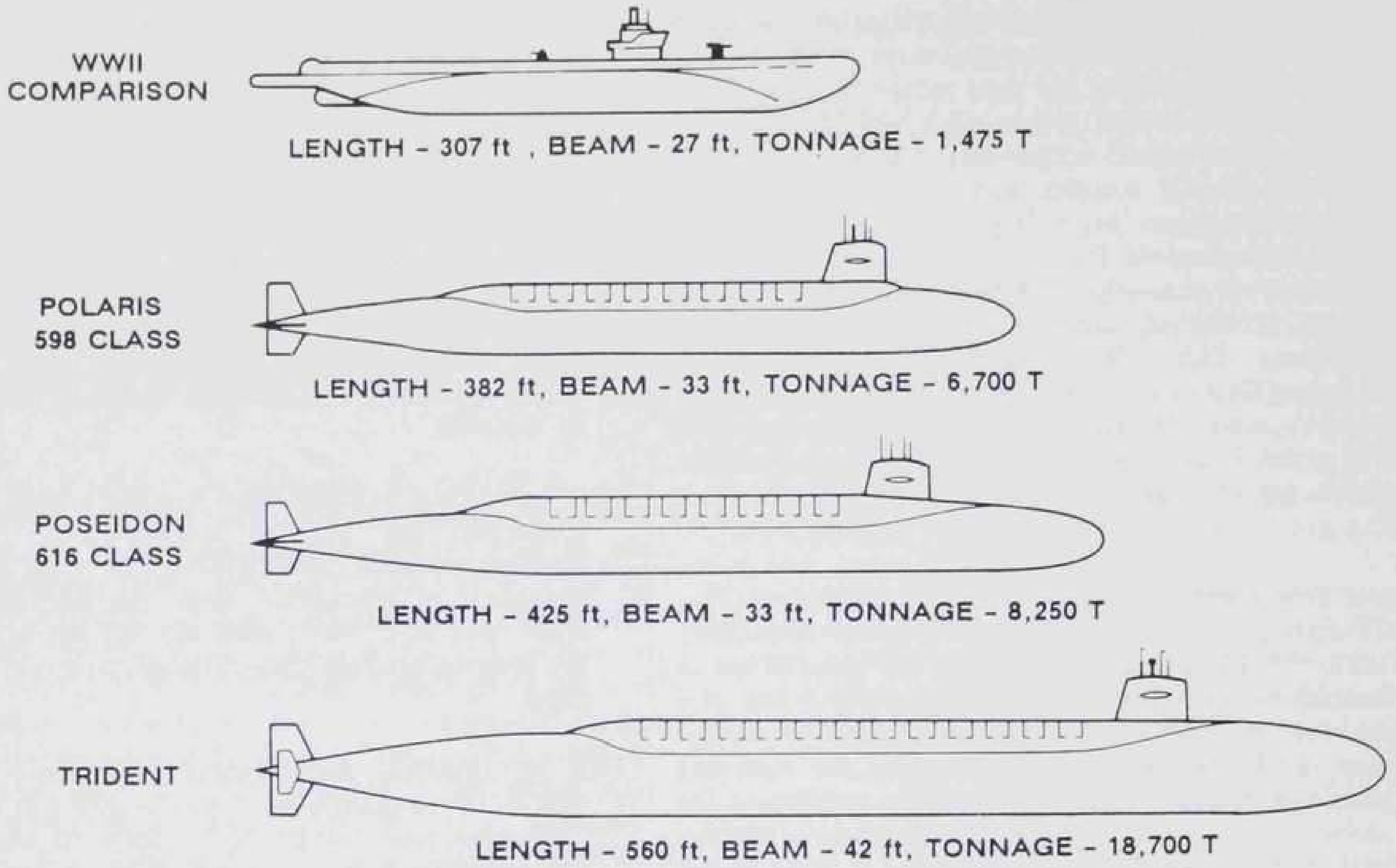


Fig. E-2 Tonnage

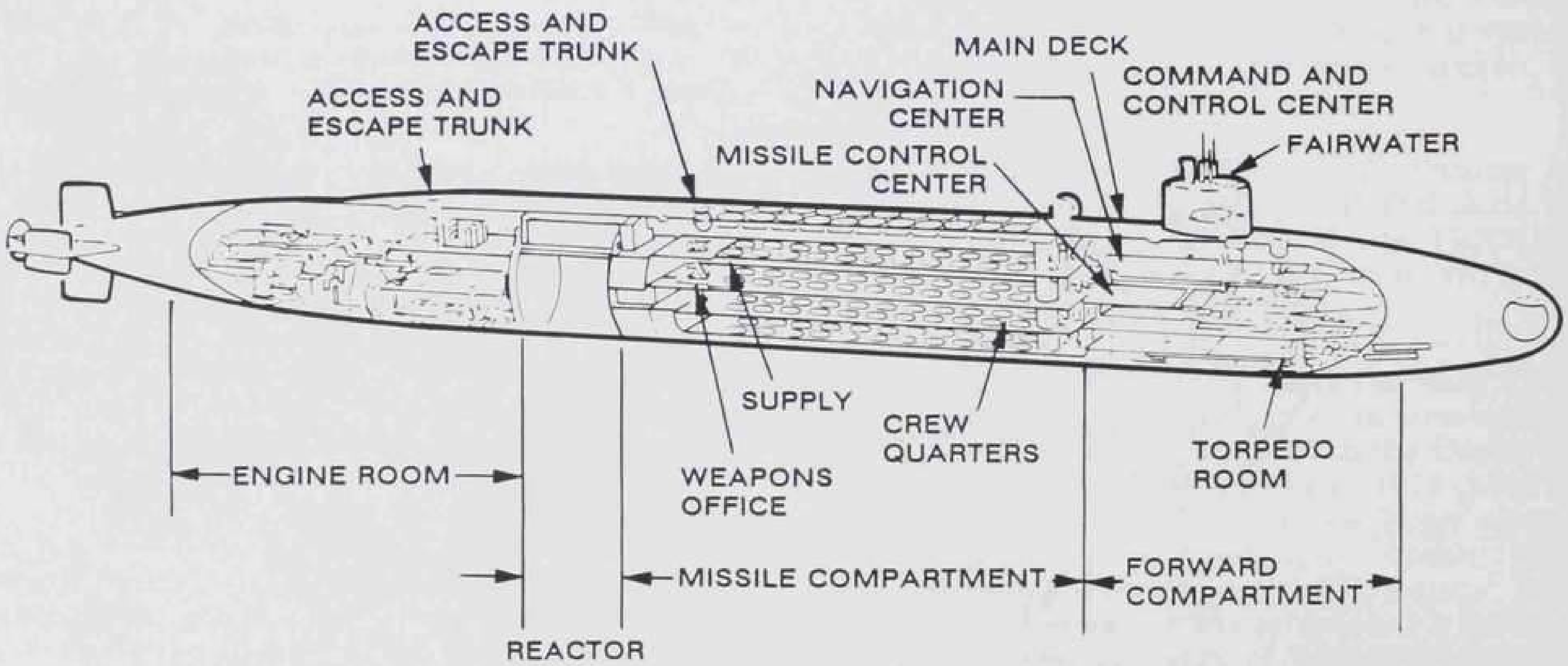


Fig. E-3 Typical C4/D5 System TRIDENT SSBN

CHARACTERISTICS	598 CLASS* (5 SUBMARINES)	608 CLASS* (5 SUBMARINES)	616 CLASS (31 SUBMARINES)	726 CLASS (TRIDENT SUBMARINES)
LENGTH	382 ft	410 ft	425 ft	560 ft
BEAM	33 ft	33 ft	33 ft	42 ft
SURFACE DISPLACEMENT	6,000 TONS	6,900 TONS	7,320 TONS	16,600 TONS
SUBMERGED DISPLACEMENT	6,700 TONS	7,900 TONS	8,250 TONS	18,700 TONS
PROPULSION	STEAM TURBINE POWERED BY WATER-COOLED NUCLEAR REACTORS	SAME	SAME	SAME
TORPEDOES	6 BOW TORPEDO TUBES	4 BOW TORPEDO TUBES	4 BOW TORPEDO TUBES	4 BOW TORPEDO TUBES
ACCOMMODATIONS OFFICER ENLISTED	13 BERTHS 127 BERTHS	12 BERTHS 127 BERTHS	14 BERTHS 133 BERTHS	16 BERTHS 148 BERTHS
MISSILES	16 POLARIS A3 MISSILES	16 POLARIS A3 MISSILES	16 POSEIDON C3 MISSILES	24 TRIDENT I (C4) TRIDENT II (D5) MISSILES
LAUNCH TUBES	16 TUBES LOCATED MIDSHIP	SAME	SAME	24 TUBES LOCATED MIDSHIP
LAUNCH CONTROL	GAS STEAM GENERATOR	AIR EJECTION	GAS STEAM GENERATOR	GAS STEAM GENERATOR
FIRE CONTROL SYSTEM	Mk 80	Mk 80	Mk 88	Mk 98
NAVIGATION SYSTEM	3 Mk 2 MOD 4 SINS (SHIPS INERTIAL NAVIGATION SYSTEM) AND NAVY NAVIGATIONAL SATELLITE RECEIVER	2 Mk 2 MOD 3 SINS AND SATELLITE RECEIVER	2 Mk 2 MOD 6 SINS SATELLITE RECEIVER	2 Mk 2 MOD 7 SINS ELECTROSTATICALLY SUPPORTED GYRO MONITOR SATELLITE RECEIVER
AIR CONDITIONING	OVER 300-TON CAPACITY	SAME	SAME	SAME

*NO LONGER ACTIVE FBM SUBMARINES

Fig. E-4 FBM Weapon System Submarine Characteristics

The superstructure is any part of the ship that is above the pressure hull. This would include the sail or fairwater area, and the area above the missile tubes.

The streamlined hull was designed specifically for efficient cruising underwater; the Skipjack was the first nuclear-powered ship to adopt this hull form.

The larger hulls accommodate more weapons of larger size and greater range, as well as sophisticated, computerized electronic equipment for improved weapon guidance and sonar performance.

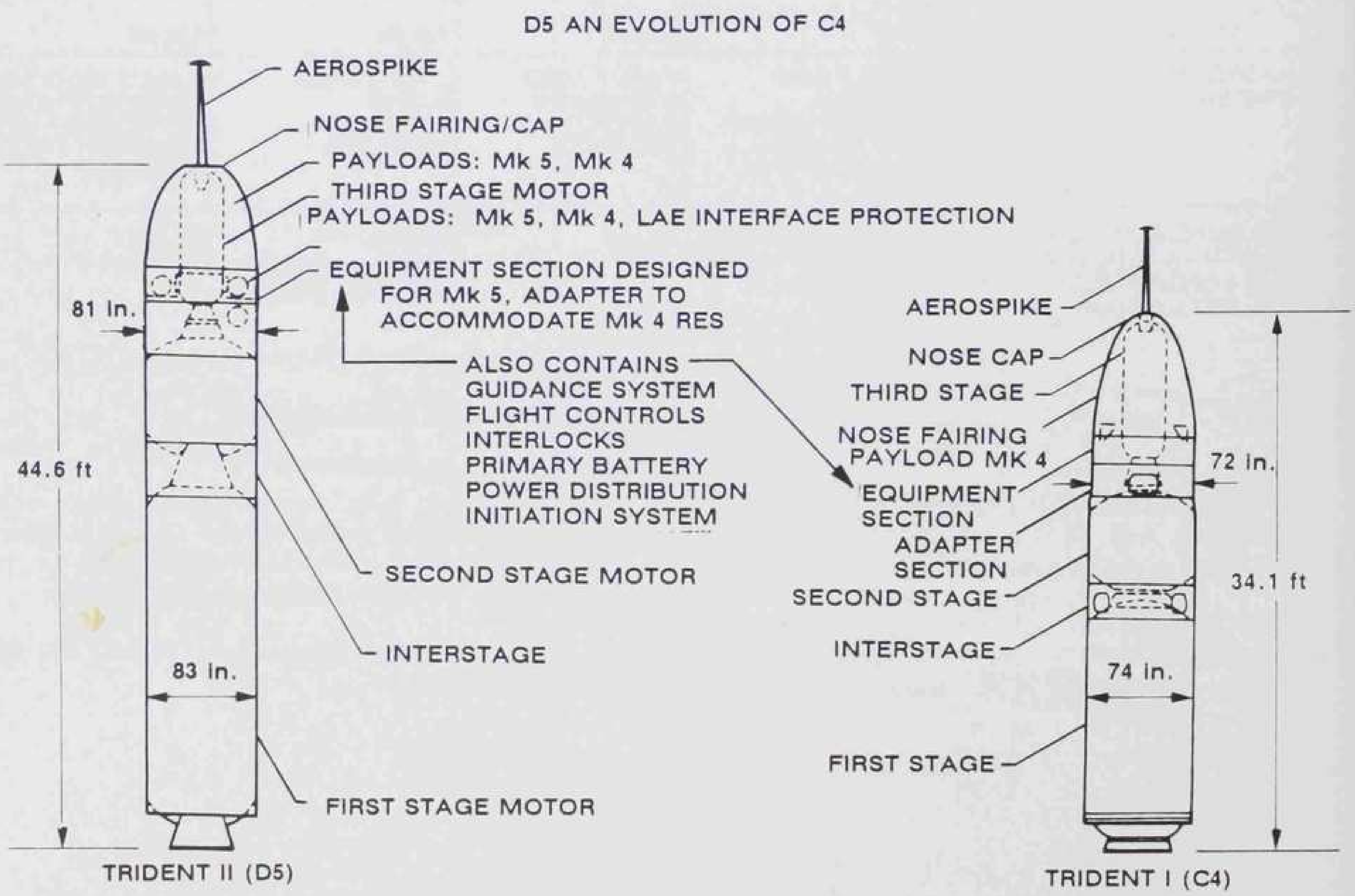
Improved silencing techniques reduce the chances of detection.

THE TRIDENT II (D5) MISSILE

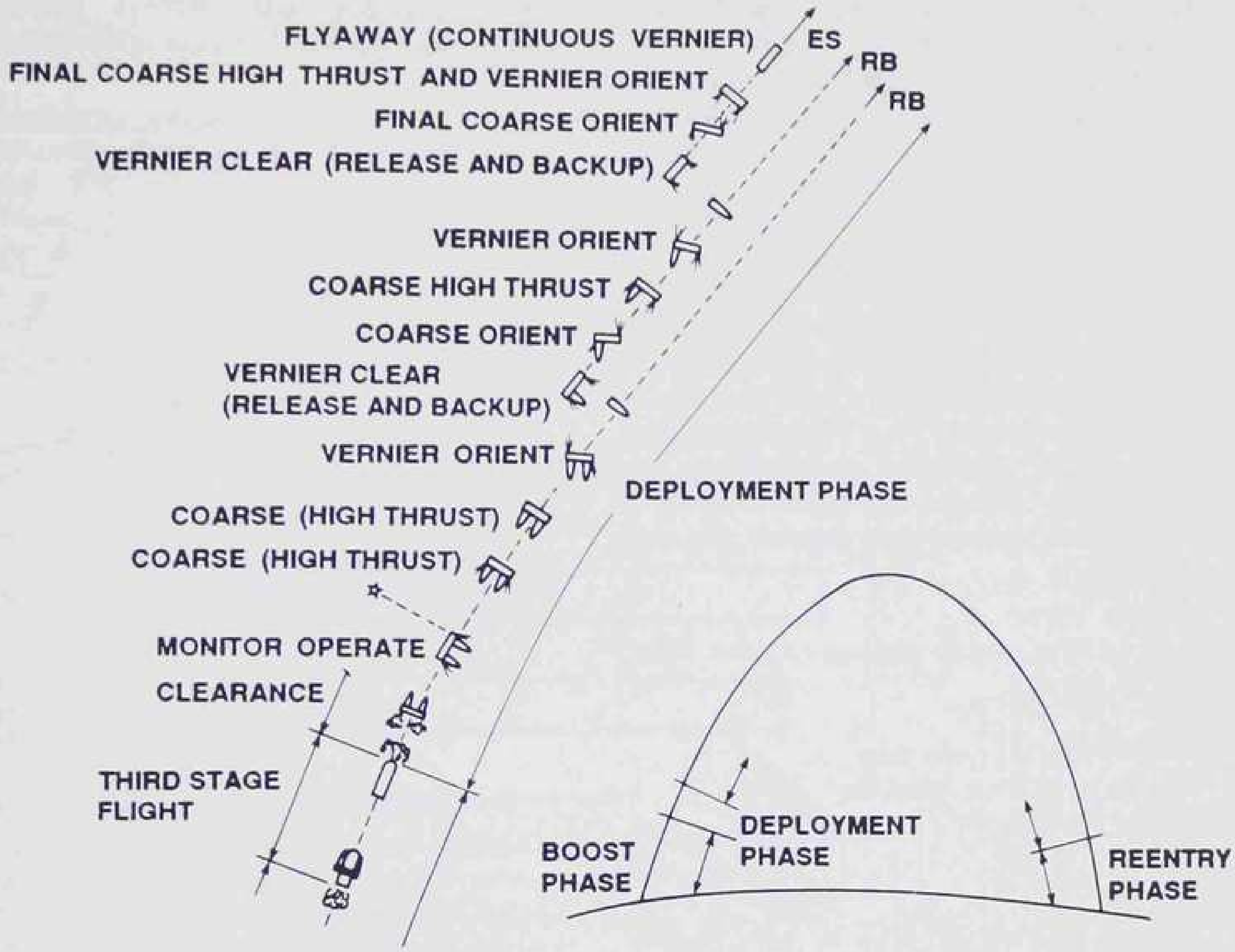
As previously stated, the TRIDENT II (D5) is an evolution of the TRIDENT I (C4). Generically speaking, the D5 looks like the C4, only bigger. It has an NF with an aerospike; three solid-propellant rocket motors, each with a single flexible nozzle; and associated TVC components. The FS and SS motors are also primary structural components of the missile, connected by an Interstage (IS). Forward of the SS motor, the adapter section structure of the C4 has been eliminated in D5, and the equipment section (ES) has been extended to serve as the adapter section plus ES. The TS motor is mounted within and to the ES similar to C4. Structural bracketry on the forward part of the ES is modified from C4, in order to accommodate the bigger Mk 5 RB or, with added fixtures, a payload of Mk 4 RBs. On the whole, D5 looks like C4, only bigger.

When compared to C4, for the D5 to achieve the longer range with its larger, heavier payload, improvements in rocket motor performance would be required plus reductions in the weight of the missile's components. To improve rocket motor performance, there was a solid-propellant change. The C4 propellant carried the name of XLDB-70, translated to cross-link double-base — 70 percent solid fuels. The solids consisted of HMX (His Majesty's Explosive), aluminum, and ammonium perchlorate. The binder of these solids was Polyglycol Adipate (PGA), Nitrocellulose (NC), Nitroglycerine (NG), and Hexad isocryanate (HDI). This propellant could have been called PGA/NG, when we consider that D5 propellant is called Polythylene Glycol (PEG)/NG. D5 is called this because the major innovation was the usage of PEG in place of the PGA in the binder. It was still a cross-link, double-base propellant. The use of PEG made the mixture more flexible, more rheologic, than the C4 mixture with PGA. Thus, the D5 mixture being more flexible, an increase could be made in the amount of solid fuels; increased to 75 percent solids resulting in improved performance. Thus, D5 propellant's is PEG/NG-75. The Joint Venture (the propulsion subcontractors, Hercules and Thiokol) have given a trade name to the propellant NEPE-75.

The motor case material on the D5's FS and SS became graphite/epoxy versus the Kevlar epoxy of C4, an inert weight saver. The TS motor was to be



TRIDENT II (D5) Baseline Missile



TRIDENT I (C4) Modes of Flight

Kevlar epoxy but, midway through the development program (1988), it was changed to graphite/epoxy. The change was a range gainer (reduced inert weight) plus eliminated any electrical static potential associated with Kevlar and graphite. There was also a change in all D5 rocket motor nozzles' throat material from segmented rings of pyrolytic graphite in the entrance and throat of the C4 nozzle to a one-piece integral throat and entrance (ITE) of carbon-carbon on D5. This change was for reliability purposes.

As mentioned, the ES was integrated with the adapter section, using graphite/epoxy versus the aluminum composite structures on C4. This was a weight saver, providing a range gainer. The IS did not change, conventional aluminum. The ES mounting for the TS rocket motor is similar for both the C4 and D5 with an explosive zip tube used for separation, and the TS motor has a similar eject rocket motor on the forward end of the TS rocket motor.

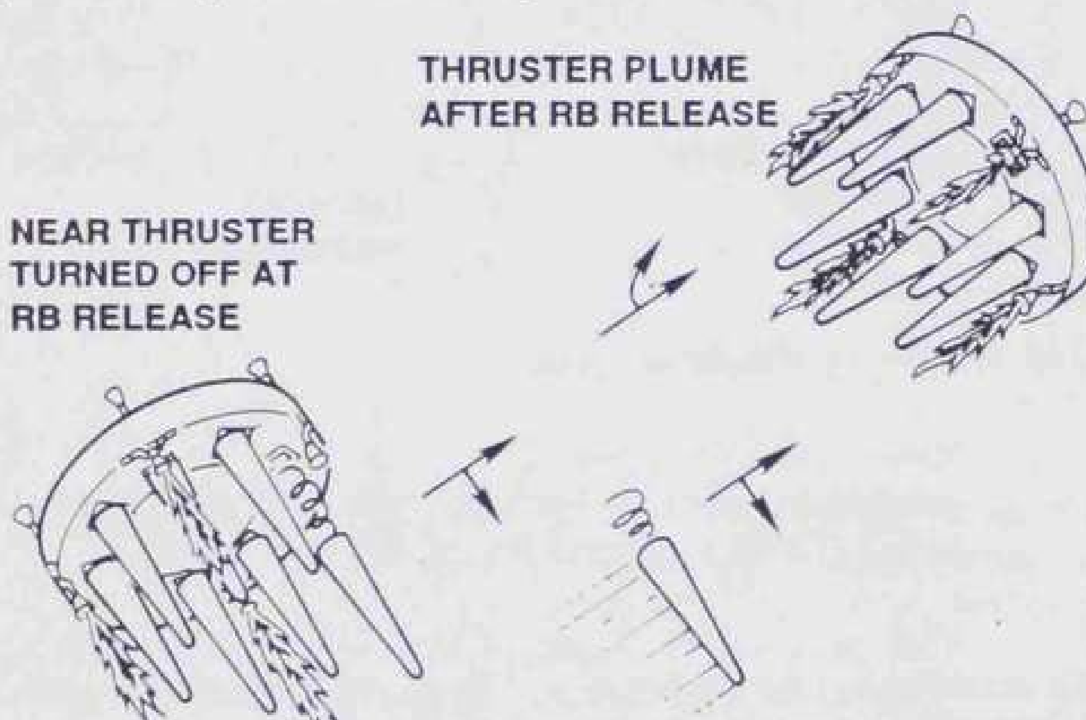
Both C4 and D5 ES PBCSs are similar except C4 had only two simultaneously burning TVC gas generators, whereas D5 has four TVC gas generators. There are two "A" generators which burn initially and provide thrust to the ES, using integrated valve assemblies (IVAs). When the gas pressure drops in the "A" generators due to burnout, the "B" generators are ignited for the remainder of the ES flight.

The post-boost flight of the C4 and D5 ES and RB releases are different. With C4, upon completion of the TS rocket motor burn and separation, the PBCS positions the ES, which is maneuvered in space to permit the guidance system to conduct its stellar sightings. Guidance then determines any flight trajectory errors and issues corrections to the ES flight path in preparation for RB deployment. The C4 ES then enters a high-thrust mode, the PBCS driving it to the proper position in space and correct velocity for RB deployment. During the high-thrust mode, the ES flies "backwards" (RBs face aft to the trajectory). When the correct velocity for RB release is obtained, the C4 ES goes into a vernier mode. (ES is adjusted so that the RB will be deployed at the proper altitude, velocity, and attitude.)

Upon completion of each RB drop, the ES backs off and moves to another position for subsequent reentry drops. During the backing off, gas plumes from the PBCS will impact on RBs differently, causing RB velocity deltas.

In the case of D5, the ES uses its PBCS to maneuver for stellar sighting; this enables the guidance system to update the original inertial guidance as received from the SSBN. The flight control system responding to guidance reorientates the D5 ES and enters a high-thrust mode. However, in the D5 case, the ES flies forward. (RBs are basically down the line of the trajectory.) As in C4, the D5 ES (when it reaches the proper altitude, velocity and attitude) enters the vernier mode to deploy RBs. However, to eliminate the PBCS plume from impacting the RB upon release, the ES undergoes a Plume Avoidance Maneuver (PAM). If the RB to be released will be disturbed by a PBCS nozzle's plume, that nozzle will be shut off until the RB is away from the nozzle's plume area. With a nozzle off, the ES will react to the other three nozzles automatically. This causes the ES to rotate as it backs away from the RB just released. In a very short time, the RB will be beyond the influence of the plume and the nozzle is returned to normal operation. PAM is used only when a nozzle's plume will disturb the area around an RB.

This PAM was one of the design changes to the D5 to provide improved accuracy.

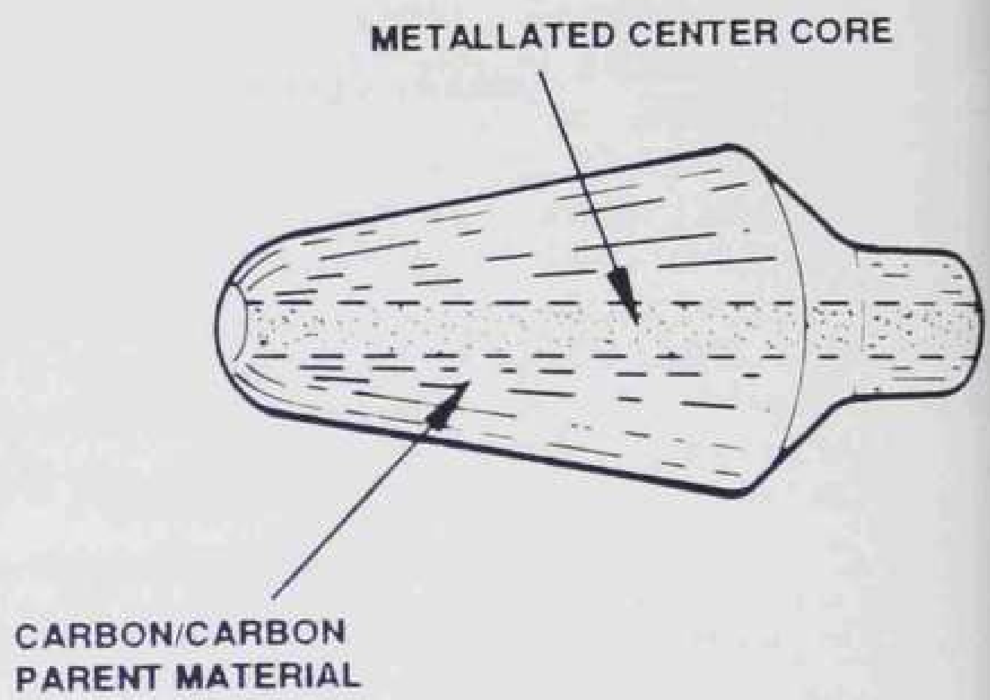


Plume Avoidance Maneuver (PAM)

Another design change to help improve accuracy was to the nosetip of the Mk 5 RB. In the TRIDENT I (C4) missile, an error condition existed in some cases upon reentry into the atmosphere when the nosetip ablated at an uneven rate. This caused the RB to drift. As the design of the Mk 5 reentry was developed, the change to a shape stable nosetip (SSNT) was established.

The nose of the Mk 4 RB was boron carbide-coated graphite material. The Mk 5 nose has a metallated center core with carbon/carbon material, forming the rest of the nosetip ("plug")).

The metallated center core will ablate at a faster rate than the carbon/carbon parent material on the outer portion of the nosetip. This will result in a blunt, more-symmetrical shape change with less of a tendency to drift and, consequently, a more-accurate and more-reliable system. Prior testing of SSNTs on some C4 missile flights had verified the desig concept.



Shape Stable Nosetip

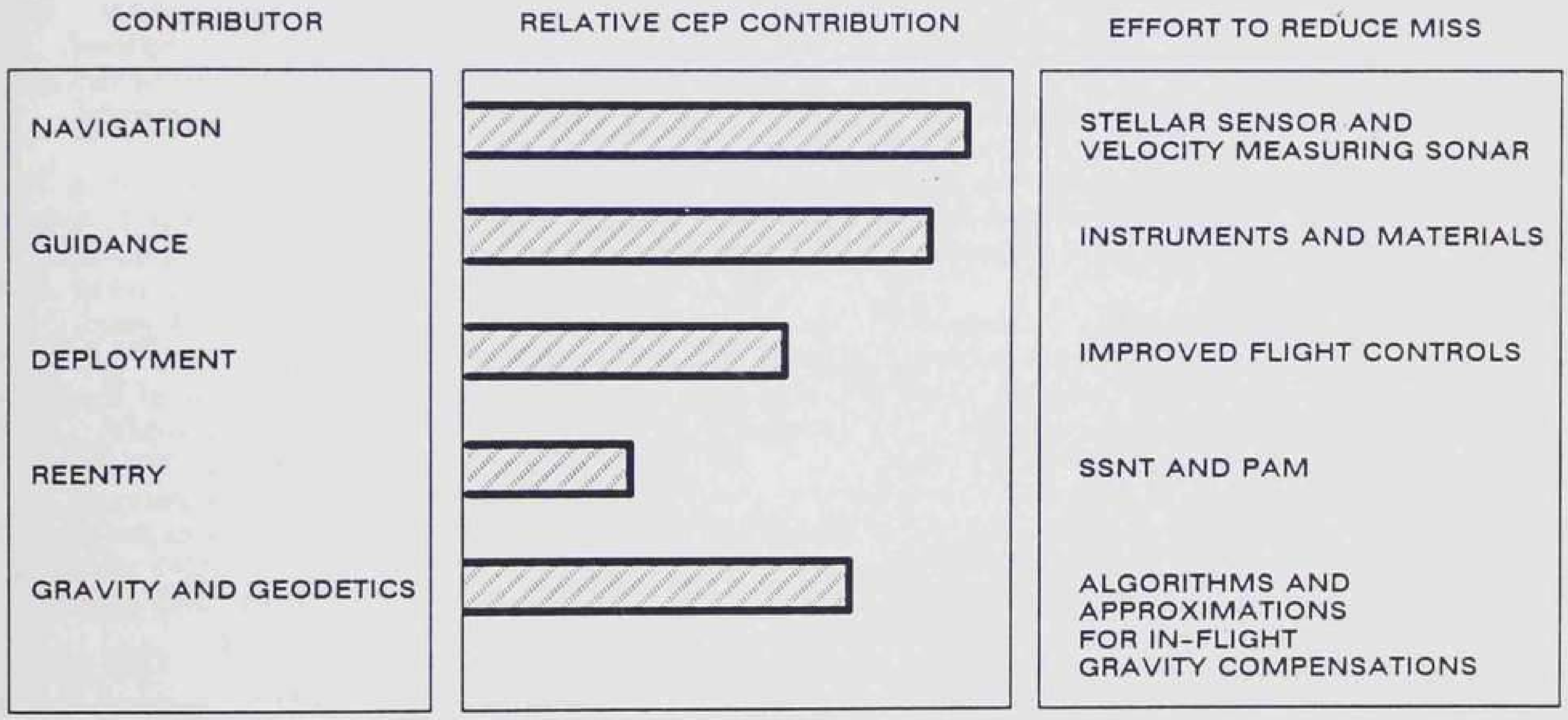
In TRIDENT I (C4), the flight control subsystem con verted data signals from the guidance subsystem int steering and valve commands (TVC commands) mod erated by missile response rates fed back from th rate gyro package. In TRIDENT II (D5), the rat gyro package was eliminated. The D5 flight contro computer receives these missile response rates from the guidance system inertial measuring unit (IMU) a transmitted through the guidance electronic assembl (EA).

Also in TRIDENT II, there was extensive use of configurable gate arrays (CGAs) in the primary logic circuits. In C4, these logic circuits (And/Or gates) were a series of integrated circuits and discrete components laid out on multi-layer boards (MLBs) to form a circuit. In D5, using CADAM (Computergraphics Augmented Design and Manufacturing), a circuit design was developed. The circuit was programmed by masking on to an "off-the-shelf" Large Scale Integration (LSI) circuit to form the logic circuit (And/Or gates), thus CGA. This provided flexibility in the design of unique circuits, ease in making the design changes, and reduced manufacturing time. The use of CGAs required less space for similar C4 functions and was also an inert weight-saving contributor.

The more-extensive use of composites in D5's structure provided inert weight savings. Redesign of ordnance system D5-versus-C4, although functionally the same, in particular the separation ordnance to "cut" structure, contributed to weight savings.

Improvements in propellant performance and reductions in inert weight tended to satisfy the requirement for range. The SSNT of the Mk 5 RB and the ES PAM maneuver, when deploying RBs, contributed to accuracy improvements. Major improvement to accuracy could also be obtained by improvements in the SSBN's navigation system, the guidance systems measurement capability, and refinements in trajectory calculations.

The IAP undertook advanced development efforts to improve, above TRIDENT I (C4), the guidance system stellar inertial components and system capabilities plus the nonstellar inertial subsystem. As a follow-on for D5, improvements were developed for the guidance system gyros, accelerometers, stellar sensors, and inertial measurement system. There were also advancements in guidance calibration and software design techniques. A new pendulous integrating gyro (PIGA) was developed — versus — the pulse integrating pendulous accelerometer of the C4, plus improved miniature inertial two-axis gyros. All of this helped reduce the guidance system contribution to target miss distance (e.g., improved CEP).



HIGHLIGHTS (1980 - 1986)

25 Jan 1980 — As part of its phase-down operations, the USS Compass Island (AG 153) completed operational support as a navigation test ship for the FBM Program. Its role would be assumed by the USNS Vanguard (TAGM-19).

Mar 1980 — Fiscal Year 1980 POLARIS A3 missile follow-on operational tests were canceled. With cancellation of these tests, the U.S. POLARIS flight test program was completed. The final flight test was conducted in April 1979.

7 Mar 1980 — In his annual report to Congress, the SECDEF announced his intention to proceed with an ADP for a submarine-launched ballistic missile modernization program.

1 May 1980 — The USS Compass Island (AG-153), which served as a navigation test ship for the FBM program since January 1957, was decomissioned.

10 Jul 1980 — The governments of the U.S. and the U.K. agreed that the U.K. would purchase TRIDENT I (C4) missiles (less warheads), equipment, and services from the U.S. The SECNAV delegated responsibility for managing U.S. Government activities relative to the sale to the Director, SSP.

28 Jul 1980 — Processing of TRIDENT I missiles commenced at SWFPAC.

1 Nov 1980 — RADM Glenwood Clark, USN, relieved RADM Robert H. Wertheim, USN, as Director, SSP.

3 Nov 1980 — The first TRIDENT I (C4) missile to be assembled at SWFPAC was completed.

Dec 1980 — The USS Ethan Allen (SSBN-608), USS Thomas A. Edison (SSBN-610), and USS San Houston (SSBN-609) ended their A3 strategic roles in August, October, and December, respectively, for a total of five in this category at year-end, the USS Theodore Roosevelt (SSBN-600) and USS Abraham Lincoln (SSBN-602) having terminated their strategic role in November 1979.

2 Feb 1981 — The SECDEF documented his decision to proceed with a submarine-launched ballistic missile modernization program by directing specific programmatic efforts and defining objectives of the ADP.

10 Feb 1981 — The pad launch phase of the U.K. A3TK development flight test program was completed. In all, 11 missiles were launched from a flat pad at Cape Canaveral.

13 Mar 1981 — The CNO approved a Naval Sea Systems Command recommendation for an extension of the POSEIDON SSBN-616 class operating cycle to 12 years.

1 Apr 1981 — The Gold Crew of the USS Simon Bolivar (SSBN-641) successfully launched one TRIDENT I (C4) missile in support of the ship's DASO. This was the first firing of a TRIDENT I (C4) missile produced at SWFPAC and airlifted to ETR for onloading.

27 Jun 1981 — The USS James Polk (SSBN-645) returned to port, marking the completion of the 2,000th SSBN deterrent patrol.

1 Jul 1981 — The submarine base (SUBASE) at Bangor, Washington, was activated under the command of the Commander in Chief, U.S. Pacific Fleet (CINCPACFLT). This was done to support the Navy's TRIDENT FBM submarines.

Jul 1981 — Submarine tender USS Proteus (AS-19) was phased out of FBM service but it remained onsite at Guam for attack submarine (SSN) support.

Sep 1981 — A contract was awarded for a qualification program, motor materials, and hardware refurbishment to provide replica new A3 motors for the U.K.

2 Oct 1981 — The SECDEF directed the Navy to fund an ADP for a TRIDENT II (D5) missile with a late 1989 IOC.

11 Nov 1981 — The USS Ohio (SSBN-726), the first TRIDENT-class nuclear-powered FBM submarine, completed construction on 28 October 1981 and was commissioned. Vice President George C. Bush was the principal speaker.

Dec 1981 — The USS Thomas Jefferson (SSBN-618), USS John Marshall (SSBN-611), USS Patrick Henry (SSBN-599), and USS George Washington (SSBN-598) terminated their A3 strategic roles in February, May, October, and November, respectively, for a total of nine in this category at year-end. The USS John Marshall (SSBN-611) was redesignated an SSN.

25 Feb 1982 — The USS Robert E. Lee (SSBN-601) began final POLARIS (A3) offload at SWFPAC. This terminates the strategic role of the U.S. A3 POLARIS fleet. A total of 1245 A3 patrols were completed. SSBN-601 was reclassified as an SSN in March.

11 Mar 1982 — In a letter to President Reagan, Prime Minister Thatcher formally requested that the U.S. Government supply TRIDENT II missiles, equipment, and support services on a continuing basis and in a manner similar to that in which POLARIS was supplied. The U.K. Government wished to purchase the TRIDENT II (D5) missiles complete with MIRVs but without the warheads. The primary reason for the British choice of the TRIDENT II missile over the TRIDENT I missile was to maintain commonality with the U.S. Navy. Although the performance of the TRIDENT I was adequate for British purposes, a long-term logistic and cost penalty would be experienced because of the uniqueness of the system once the U.S. Navy made the transition to the TRIDENT II missile. In response to Prime Minister Thatcher's request, President Reagan formally agreed to supply the U.K. with the TRIDENT II missiles, equipment, and supporting services. The President's letter welcomed Prime Minister Thatcher's commitment to use the savings from cooperation in the strategic nuclear field to strengthen British conventional forces which were vital to the NATO deterrent.

12 Mar 1982 — The USS Ohio (SSBN-726) successfully launched a TRIDENT I (C4) missile in support of the ship's DASO.

28 Apr 1982 — The Vice CNO provided the CNM an updated statement of the TRIDENT II (D5) Weapon System Program Objectives. Among other things, specific objectives were to maintain the survivability of the submarine-launched ballistic missile launch platform and to enhance U.S. strategic posture by adding prompt hard-target kill capability to the submarine-launched ballistic missile arsenal. The TRIDENT II objectives were to be reviewed and revised, as necessary, based on trade-off information that would become available during the ADP phase of the TRIDENT II program.

1 Jun 1982 — The SECDEF advised the Chairman of the House of Representatives and Senate Committees on Armed Services (HASC/SASC) and on Appropriations (HAC/SAC) of his decision not to accelerate development of the TRIDENT II (D5) missile, but to rephase introduction of the missile into the fleet. The rephasing resulted in introducing the D5 system into TRIDENT submarines from the keel up, commencing with the ninth TRIDENT hull. Previously, the plan had been to introduce the TRIDENT II (D5) system by backfitting the 13th TRIDENT hull.

25 Aug 1982 — The arrival of the USS Ohio (SSBN-726) at Bangor, Washington, culminated the integration of the principal TRIDENT element — the ship, missile, and dedicated support base — into an operational system.

20 Sep 1982 — The SECNAV delegated additional responsibilities to the Director, SSP, as the U.S. Projects Officer under the U.S./U.K. POLARIS Sales

Agreement. The SSP Director was now authorized to manage U.S. Government activities relative to the sale of TRIDENT II (D5) to the U.K. and, in addition, to enter into the technical arrangements contemplated by the POLARIS Sales Agreement relative to that sale.

1 Oct 1982 — The TRIDENT system IOC was attained as the USS Ohio (SSBN-726) departed on the first TRIDENT deterrent patrol. It had completed strategic loadout at SWFPAC, Bremerton, Washington, and entered deployed status on 6 September 1982.

10 Dec 1982 — The USS Ohio (SSBN-726) returned from the first TRIDENT deterrent patrol.

31 Dec 1982 — By the end of calendar year 1982, 2,119 POLARIS (A3)/POSEIDON (C3)/TRIDENT I (C4) FBM strategic deterrent patrols were successfully completed. The last C4 pierside backfit SSBN, USS Stonewall Jackson (SSBN-634), completed outload at POMFLANT in February. Four other C4 backfit SSBNs, converted from C3 to C4 during overhaul, also completed outload at POMFLANT during the year: the USS Benjamin Franklin (SSBN-640) in April, the USS George Bancroft (SSBN-643) in July, the USS James Madison (SSBN-627) in August, and the USS Von Steuben (SSBN-632) in December. This brings the total C4 backfit SSBN outloads to 11 outloads — 6 pierside backfits and 5 overhaul backfits. One overhaul backfit submarine, the USS Casimir Pulaski (SSBN-633), remained to be outloaded at POMFLANT in 1983, making a total of 12 conversions.

21 Mar 1983 — The Director, SSP, proposed that SWFLANT be established as a shore facility, in an active development status, effective 1 May 1983.

3 Jun 1983 — The last of 12 C3 to C4 backfit SSBNs, the USS Casimir Pulaski (SSBN-633), completed outload at POMFLANT and deployed.

30 Jun 1983 — The responsibility for acquisition of Naval SUBASE, King's Bay, was transferred to SSPO because of the disestablishment of PM-2.

14 Aug 1983 — The USS Michigan (SSBN-727), the second TRIDENT submarine, departed SUBASE, Bangor, on her first strategic deterrent patrol with C4's.

1 Oct 1983 — The SSPO began full-scale engineering development of the TRIDENT II (D5) SWS. Development commenced following 3 years of advanced development and a review for readiness to proceed into engineering development by the DSARC on 26 September 1983.

28 Oct 1983 — For the initial phases of the TRIDENT II (D5) development program, the SSPO executed letter contracts with Westinghouse Electric Corporation for launcher, with General Electric Ordnance Systems for fire control, with Interstate Electronics Corporation for test instrumentation, and with LMSC for missile. These letter contracts and a contract with Sperry Systems Management for navigation would be definitized as OSDP contracts. A letter contract was executed also for guidance subsystem development but not for the OSDP form of contracting because, although developed by Charles Stark Draper Laboratory, the guidance system is produced by other contractors.

1 Dec 1983 — The SSNs, USS Robert E. Lee and USS Thomas A. Edison (formerly SSBNs 601 and 610, respectively), were decommissioned. The submarines were over 21 years old at the end of their service life.

31 Jan 1984 — The USS Proteus (AS-19) celebrated her 40th birthday. The USS Proteus (AS-19) had been selected as the first submarine tender to be converted to support POLARIS FBM submarines.

7 Mar 1984 — The Strategic Systems Project Office became the Strategic Systems Programs Office.

11 May 1984 — The USS Florida (SSBN-728), the third TRIDENT submarine,

deployed on her first strategic deterrent patrol.

4 Sep 1984 — Groundbreaking ceremonies were held for the TRIDENT Training Facility (TRITRAFAC) at Naval SUBASE, King's Bay, Georgia. Construction of the facility was scheduled to be completed in December 1986.

Nov 1984 — The USS Georgia (SSBN-729) the fourth TRIDENT submarine, was outloaded.

9 Apr 1985 — The Office of the Assistant SECDEF advised that the SECNAV and the CNO have announced the disestablishment of the Naval Material Command.

6 May 1985 — The CNO advised that the SECNAV had approved the establishment of the Strategic System Programs Office (SSPO) an Echelon 2 command.

20 Jun 1985 — RADM Kenneth C. Malley relieved RADM Glenwood Clark as Director, SSP. Upon relief of duties, RADM Clark was promoted to the grade of Vice Admiral and appointed Commander of the Navy's Space and Warfare Systems Command.

21 Aug 1985 — The USS Sam Rayburn (SSBN-635) commenced final strategic offload prior to dismantlement. This was the first POSEIDON (C3) submarine to be retired in compliance with SALT.

Aug 1985 — The USS Henry Jackson (SSBN-730), the fifth of eight TRIDENT SSBNs, outloaded.

16 Sep 1985 — The USS Sam Rayburn (SSBN-635) commenced dismantlement.

17 Nov 1985 — The SSPO recognized its 30th anniversary. The celebration was held at the Washington Hilton on 2 November with all six directors, past and present, in attendance.

Jan 1986 — With the 570th delivery, LMSC, Sunnyvale Manufacturing completed the TRIDENT I (C4) missile body production program.

21 April 1986 — The USS Nathan Hale (SSBN-623) was the second submarine to offload C3 missiles at POMFLANT prior to being retired in compliance with the arms control allowance of SALT.

2 May 1986 — The USS Nathanael Greene (SSBN-636) became the third submarine to offload C3's in compliance with SALT.

10 May 1986 — The USS Alabama (SSBN-731), the sixth TRIDENT SSBN, departed on her first strategic patrol.

Sep 1986 — The USS Alaska (SSBN-732), the seventh TRIDENT SSBN, outloaded.

June 1987 — Problems related to the goals for transmission of real time flight test data between DARC (Data Acquisition and Reduction Center) at ETR and MDC (Missile Data Center) at LMSC were resolved in time for the flight of D5X-4.

July 1987 — Missile Test and Readiness Equipment (MTRE Mk 9) was delivered on schedule for the USS Tennessee (SSBN-734), the first D5 submarine. This was followed by delivery of the MTRE Mk 10 to the shipyard prior to 1 September 1987 for scheduled September installation in the SSBN-734.

August 1987 — The USS Nevada (SSBN-733), the last of eight TRIDENT SSBNs outloaded with TRIDENT (C4) missiles at SWFPAC for patrol in the Pacific.

6 July 1988 — The USS John Adams (SSBN-620) was the fifth submarine to offload C3's in compliance with SALT.

17 Dec 1988 — The USS Tennessee (SSBN-734) was commissioned.

D5X FLIGHT TEST PROGRAM (1987 - 1989)

D5 General Characteristics

The D5 missile is an evolution of the C4 missile, but bigger, to provide for additional thrust and increased payload capability. The D5 is 83 in. in diameter versus 74 in. for C4, and 44.6 ft in length versus 34.1 ft for C4. Both missiles taper to 81 in. and 71 in., respectively, forward of the SS motor.

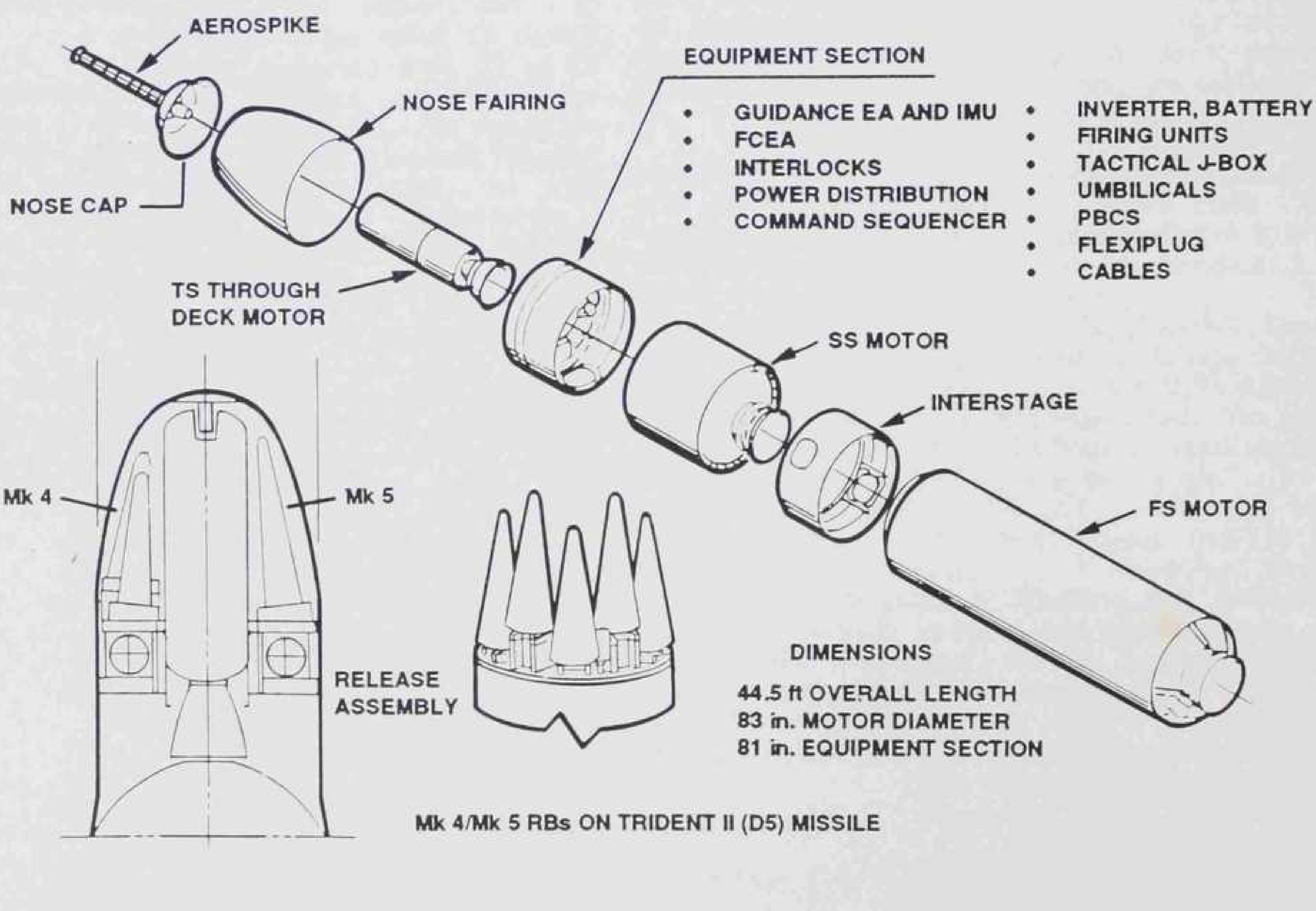
The missile consists of a FS section, an IS section, a SS section, an ES, a NF section, and a nose cap section. There is no adapter section like there is on C4. The D5 ES, along with containing all the guidance and electronics, performs the same function as the ES-adapter section in C4 (e.g., structural support between the aft end of the NF and the forward end of the SS motor).

The FS section includes the FS rocket motor, TVC system, and the components to initiate FS ignition. The IS section connects the FS and SS sections and contains electrical and ordnance equipment. The SS section includes the SS rocket motor, TVC system, and components to initiate SS ignition.

The ES houses the major guidance and flight control electronics packages. The TS rocket motor and its TVC system are mounted to an eject cylinder at the center of the ES and extends forward of the ES. A small TS eject motor is recessed in a cavity on the TS motor forward dome. When the TS motor is expended, the eject motor pushes the TS motor aft, out of the ES to effect TS separation.

The NF section covers the reentry subsystem components and the forward portion of the TS motor. The NF section consists of a primary structure with provisions for two jettison rocket motors and a locking mechanism. The nose cap assembly at the forward end of the NF houses an extendable aerodynamic spike.

The D5 missile has the capability of carrying either Mk 4 or Mk 5 RBs as its payload. The D5 reentry subsystem consists of either Mk 4 or Mk 5 RB assemblies attached by four captive bolts to their release assembly and mounted on the ES. STAS and prearming signals are transferred to each RB shortly before deployment through the separation sequencer unit. When released, the RB follows a ballistic trajectory to the target where detonation occurs in accordance with the fuze option selected by fire control through the preset subsystem.



Mk 4/Mk 5 RBs ON TRIDENT II (D5) MISSILE

The RB contains an AF&F assembly, a nuclear assembly, and electronics. The AF&F provides a safeguard to prevent detonation of the warhead during storage and inhibits RB detonation until all qualifying arming inputs have been received. The nuclear assembly is a Department of Energy (DoE) supplied physics package.

The D5 Development Flight Test Program originally consisted of 20 D5X missile flat pad flights and 10 PEM flights from a TRIDENT SSBN. Flight testing began in January 1987 and in 1988. The program was reduced to 19 D5Xs and 9 PEMs.

The following are excerpts from the GAO report (Reference 22) as released by Les Aspin, Chairman of The House Armed Services Committee.

"The flight test program, consisting of 19 missile tests from a land-based launch platform at Cape Canaveral, Florida, is about four-fifths complete. This program tests predominately the missile and the guidance subsystems of the weapon system. It began in January 1987 and is scheduled to be completed in January 1989. The overall performance results from the tests indicate that the missile is achieving its objectives for this phase of the program. Of the 15 tests conducted as of September 30, 1988, 11 were successful, 1 was partially successful, 2 were failures, and one was a "no-test." Although the majority of the tests were successful, each of the failures involved different problems and occurred at different stages of the missile flight. The most recent flight test (the 15th) was destroyed by command destruct early in its flight. According to SSP, the missile was performing normally at the time the decision was made to destruct: therefore, the flight was a no-test."

"In March 1989, SSP plans to begin a series of nine missile launch evaluations from the SSBN 734. These tests, scheduled for completion in July 1989, are intended to demonstrate the ability of the Trident II system to launch missiles from the submarine at sea to predetermined target areas. During the first 3 years of deployment, the Navy plans to continue operational testing of the Trident II from deployed Trident submarines."

"A problem encountered during the seventh flight requires a redesign of the Post Boost Control System. During the deployment phase of the seventh flight, one of the valves in the system, which controls the flow of hot gases through the system, remained closed and limited the system's steering capability. Engineering evaluations indicate there was overheating or contamination in the valve, causing it to stay closed. The redesign is to be incorporated during the 1989 testing program."

"During the ninth flight test, the missile lost control and went off course about 14 seconds into third stage flight and self-destructed. Engineering verification of the failure indicated that a short in one of the power supplies, which control the flight control computer, prevented the computer from providing the proper steering commands for the missile's third stage. The

TRIDENT D5X FLIGHT TEST SUMMARY

Flight Test Number	Reentry Body Type	Date of Test	Summary of Results
1	Mk 5	01/15/87	Successful
2	Mk 5	03/17/87	Successful
3	Mk 5	04/30/87	Successful
4	Mk 5	06/12/87	Successful
5	Mk 5	07/20/87	Successful
6	Mk 4	09/08/87	Successful
7	Mk 5	10/06/87	Partially successful, malfunction Post Boost Control System and electronics package
8	Mk 5	12/11/87	Successful
9	Mk 5	01/21/88	Failure, malfunction in flight controls electronics
10	Mk 5	04/07/88	Successful
11	Mk 5	04/28/88	Successful
12	Mk 4	05/26/88	Successful
13	Mk 5	07/07/88	Failure thrust vector control subsystem problem under investigation
14	Mk 5	08/20/88	Successful
15	Mk 5	09/19/88	No test

problem was solved through minor changes in the flight control computer. Also, there has been no reoccurrence of the problem in subsequent flight tests."

"During the 13th flight, the missile encountered a problem with the thrust vector control subsystem on its first stage, causing it to lose control and go off course about 55 seconds into flight. The missile was destroyed by the range safety officer for safety reasons. The problem is under investigation."

"During the 15th flight, the missile was destroyed by command destruct early in its flight. The missile was performing normally at the time the decision was made to destruct, thus resulting in a no test. A combination of events prompted the destruct action, including the specific trajectory selected to be flown, the prelaunch weather conditions, and the missile dynamics along the flight path, which resulted in the missile looking to the range safety officer as though it would cross the boundaries of the safety corridor."

TRIDENT SYSTEM PROJECT (PM-2)

The Director of SP (Special Projects, Strategic Systems Programs, etc. — SP-00) has been known as PM-1 for some time. With the advent of TRIDENT, PM-2 (Project Manager-2) came into being.

Upon completion of the STRAT-X study, the CNO established the ULMS program. It encompassed various studies in the areas of submarine design, missile design, sonar, countermeasures, underwater launch/missile capsules, etc. Various organizations of the Navy were involved along with internal reorganizations and shifting areas of responsibility. In essence, various organizations in the CNO's operational staff were involved (OP-971, OP-31, OP-21) along with NAVSHIPS (PMS-381, PMS-396), Naval Materiel Command, Naval Electronics Command (PME-117), and PM-1.

The following contains excerpts from reference (13).

Concept Formulation (November 1971 to May 1972)

At this juncture in ULMS development, the CNO concluded that an organization was needed which would provide planning, direction, control, and integration of the program within the Naval Materiel Command (NAVMAT). Therefore, the ULMS Project Office (PM-2) was established on 30 March 1971 with RADM H. E. Lyon as the Project Manager. Shortly thereafter, the Assistant SECNAV (R&D) designated PM-2 as an administering office for RDT&E,N funds, thereby providing PM-2 with an important program management tool.

PM-2 was to direct and manage all ULMS' development and acquisition effort (concepts for a new nuclear-powered ballistic missile submarine, a new submarine-launched ballistic missile, and a dedicated logistic support option).

The PM-2, a rear admiral, was to be assisted by a ship technical manager, ULMS Ship Acquisition Project (PMS 396), and a missile technical manager, Director of SSP (SP-00). These technical managers were assisted by two design contractors: Electric Boat Division of General Dynamics Corporation for the submarine, and LMSC for the missile. An important decision made during this phase was a bare-launch mode instead of an encapsulated-launch mode for the missile. Program objectives were specified in September 1971 when the Deputy SECDEF approved ULMS DCP No. 67. This phase concluded in May 1972 when the SECDEF changed the program name to TRIDENT System.

Discussions Through Production Approval (May 1972 to December 1976)

Following DCP approval, the TRIDENT submarine, missile, and logistic requirements; characteristics; and contractual and organizational relationships were further defined. The TRIDENT System was examined on several occasions during DSARC review meetings. The culmination of these meetings was TRIDENT submarine production approval in October 1974 and TRIDENT I missile production approval in December 1976.

TRIDENT submarine characteristics were approved by the CNO in January 1973. The program was afforded the nation's highest priority designator, BRICKBAT (DX), and approval was granted for concurrency of development and production efforts. LMSC became the contractor for development and production of the TRIDENT I missile. Electric Boat and the Newport News Shipbuilding and Drydock Company competitively bid for construction of the initial TRIDENT submarine, with Electric Boat winning the bid. Thereafter, the Newport News Shipbuilding and Drydock Company never responded to a TRIDENT submarine construction request for proposal, and Electric Boat became the sole-source contractor. Environmental statements were approved for the TRIDENT Ship System; TRIDENT SWS; Cape Canaveral, Florida; and Bangor, Washington. During this phase, various programmatic and budgetary decisions changed the TRIDENT I missile IOC from calendar year (CY) 1977 to fiscal year (FY) 1979 and established the TRIDENT System IOC as FY 1979 and TRIDENT II IOC as FY 1982. Budgetary decisions also caused three stretchouts of the submarine building rate. Bangor, Washington, was selected as the initial TRIDENT support site.

Preparation for TRIDENT I Missile Deployment (January 1977 to October 1979)

During the preparation phase for TRIDENT I missile deployment, the flatpad missile flight test and at-sea PEM flight test programs were conducted successfully. Culmination of these missile test programs allowed the USS Francis Scott Key (SSBN-657) to deploy on patrol with TRIDENT I missiles on 20 October 1979. Production problems at Electric Boat caused the lead TRIDENT submarine delivery date to be delayed until November 1980 with a consequent delay of TRIDENT System IOC until FY 1982. Programmatic and budgetary decisions caused two additional stretchouts of the submarine building rate and changed the TRIDENT II IOC to FY 1990. An environmental statement was approved for King's Bay, Georgia, and Submarine Squadron Sixteen, formerly supported at Rota, Spain, commenced operations from this location in July 1979. King's Bay became the tender-refit site for POSEIDON submarines backfitted with the TRIDENT I missile. The SECNAV made a preliminary decision to develop King's Bay into a TRIDENT support site. The lead TRIDENT submarine, the USS Ohio (SSBN-726), was launched and christened.

Preparation for TRIDENT System Deployment (November 1979 to October 1982)

Continued production problems at Electric Boat projected further delivery delay for the USS Ohio (SSBN-726) until October 1981 with consequent delay of the TRIDENT System IOC until FY 1983. However, following highly-successful builder's sea trials and Board of Inspection and Survey (INSURV) trials, the lead ship was delivered to the Navy and commissioned the USS Ohio (SSBN-726) on 11 November 1981. The commands at Bangor, Washington, were fully activated on 1 July 1981. Following successful shakedown operations, including launch of TRIDENT I missiles, the USS Ohio (SSBN-726) arrived at Bangor, Washington, for the initial predeployment refit. Outloading with missiles on 6 September 1982, the USS Ohio (SSBN-726) deployed on her initial patrol on 1 October 1982, thus attaining TRIDENT System IOC. During this phase, the second TRIDENT submarine was delivered and commissioned the USS Michigan (SSBN-727), 1 month ahead of schedule, and the third ship, the USS Florida (SSBN-728), was launched and christened. Two additional ship construction rate stretchouts occurred due to programmatic and budgetary decisions; the SECNAV made a final decision to provide TRIDENT system support at King's Bay; and the Deputy SECDEF directed that the TRIDENT II IOC be December 1989.

Preparation for TRIDENT II Missile Deployment (October 1982 to August 1983)

The final phase of the project history deals with the development and acquisition of the TRIDENT II missile for the TRIDENT System. The current shipbuilding contract with Electric Boat was modified to include the TRIDENT II SWS in the ninth and subsequent TRIDENT submarines. The USS Florida (SSBN-728) was delivered and commissioned, and the fourth TRIDENT ship, USS Georgia, was launched and christened. The SECNAV directed that the disestablishment of PM-2 occur by 30 August 1983 with functional responsibilities transferring to SSPO, NAVSEA, and Commander Submarine Force, U.S. Pacific Fleet (COMSUBPAC). PM-2's functions were divided into four blocks for transfer, all four blocks of functions were transferred, and PM-2 was disestablished on 30 June 1983. The Director, SSP, has become the TRIDENT missile system technical manager and acquisition manager for King's Bay, Georgia, and NAVSEA has become the technical manager for TRIDENT submarine construction and overhaul.

PM-2 MILESTONES

TRIDENT SYSTEM PROJECT

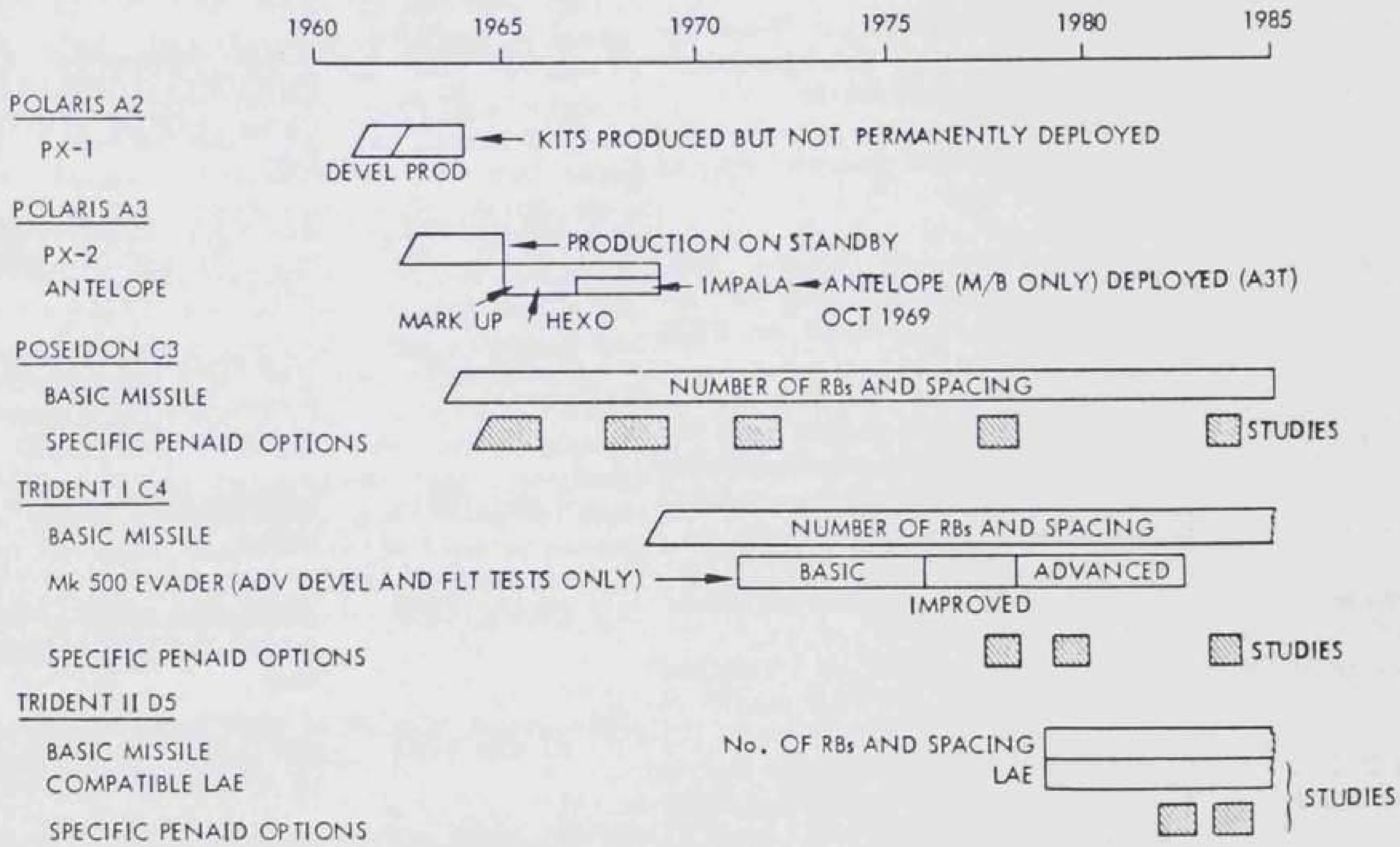
21 Dec 1968	SPO redesignated as SSPO by NAVMATINST 5430.37
4 Oct 1969	OPNAVINST C5441.8 formally established ULMS program
30 Mar 1971	ULMS Project established by NAVMATINST 5430.45; RADM H. E. Lyon designated as PM-2
27 Apr 1971	ULMS submarine design contract awarded to Electric Boat
14 Sep 1971	Deputy SECDEF approved ULMS DCP No. 67
9 Nov 1971	41 ft pressure hull diameter selected by PM-2
30 Nov 1971	LMSC awarded initial ULMS missile development contract
14 Dec 1971	DSARC program review
15 May 1972	ULMS renamed TRIDENT System
14 Dec 1972	Submarine DSARC II meeting
14 Dec 1972	TRIDENT System project assigned BRICKBAT (DX) priority and Rapid Development Capability (RDC)
9 Feb 1973	Deputy SECDEF provided the submarine DSARC II decisions
16 Feb 1973	Bangor, Washington, selected as initial TRIDENT system support site
4 Mar 1973	SECDEF decision on 24 missile tubes
18 Oct 1973	Missile DSARC II; DCP No. 67, Cover Sheet No. 1 approved by Deputy SECDEF
25 Jul 1974	Contract for construction of first TRIDENT submarine signed with Electric Boat
19 Aug 1974	Missile system OSDP contract awarded
17 Oct 1974	Submarine DSARC III

13 Dec 1974	Deputy SECDEF provided the submarine DSARC III decisions
30 May 1975	RADM J. C. Metzel, Jr., assumed duty as PM-2
8 Apr 1976	Newport News Shipbuilding and Drydock Company declined a response to the second request for proposal (RFP) for TRIDENT submarine construction
23 Dec 1976	Missile DSARC III
17 Jan 1977	Deputy SECDEF approved DCP No. 67, Cover Sheet No. 3 and provided missile DSARC III decisions
1 Feb 1977	Naval SUBASE, Bangor, Washington, activated in a developmental-limited operational status
30 Sep 1977	RADM D. P. Hall assumed duty as PM-2
17 Jan 1978	SECNAV selected King's Bay, Georgia, as the refit site for C4 backfit submarines based on FEIS approval
5 Dec 1978	SSBN Strategic Submarine Refit Siting Steering Group recommended King's Bay as the Atlantic coast location for TRIDENT support
2 Mar 1979	SSBN-X project assigned to PM-2
26 Apr 1979	RADM J. D. Murray, Jr., assumed duty as PM-2
24 May 1979	SECNAV announced King's Bay as the preferred Atlantic coast location for TRIDENT support
2 Jul 1979	USS Simon Lake (AS-33) moored at NAVSUBSUPPBASE, King's Bay
20 Oct 1979	USS Francis Scott Key (SSBN-657) deployed with TRIDENT I (C4) missiles onboard; C4 IOC attained
21 May 1980	Commander, Submarine Group Nine (COMSUBGRU 9) and Commander, Submarine Squadron Seventeen (COMSUBRON 17) established
10 Jul 1980	SWFPAC commenced processing TRIDENT I missiles
23 Oct 1980	SECNAV announced King's Bay as a site for TRIDENT support
10 Mar 1981	SSBN-X project terminated
1 Jul 1981	SUBASE, TRIREFFAC, TRITRAFAC, Bangor activated
31 Jul 1981	RADM S. G. Catola assumed duty as PM-2
17 Jan 1982	TRIDENT System launch of first TRIDENT I (C4) missile during USS Ohio DASOs
1 Apr 1982	Naval Submarine Support Base (NAVSUBSUPPBASE) King's Bay name changed to SUBASE, King's Bay
3 Aug 1982	SECNAV announced disestablishment of PM-2; effective 30 June 1983
1 Oct 1982	USS Ohio (SSBN-726) deployed on patrol; TRIDENT System IOC attained
1 Oct 1982	TRIREFFAC King's Bay established
13 Oct 1982	SSBN-726 class submarine integrated logistics support (ILS) certified
27 Oct 1982	PM-2 Block 1 functions transferred to NAVSEA and SSPO
16 Nov 1982	Electric Boat shipbuilding contract modified to add TRIDENT II (D5) SWS to ninth ship
1 Feb 1983	PM-2 Block 2 functions transferred to NAVSEA and SSPO
1 Apr 1983	PM-2 Block 3 functions transferred to NAVSEA and COMSUBPAC
30 Jun 1983	PM-2 Block 4 functions transferred to SSPO
30 Jun 1983	PM-2 disestablished

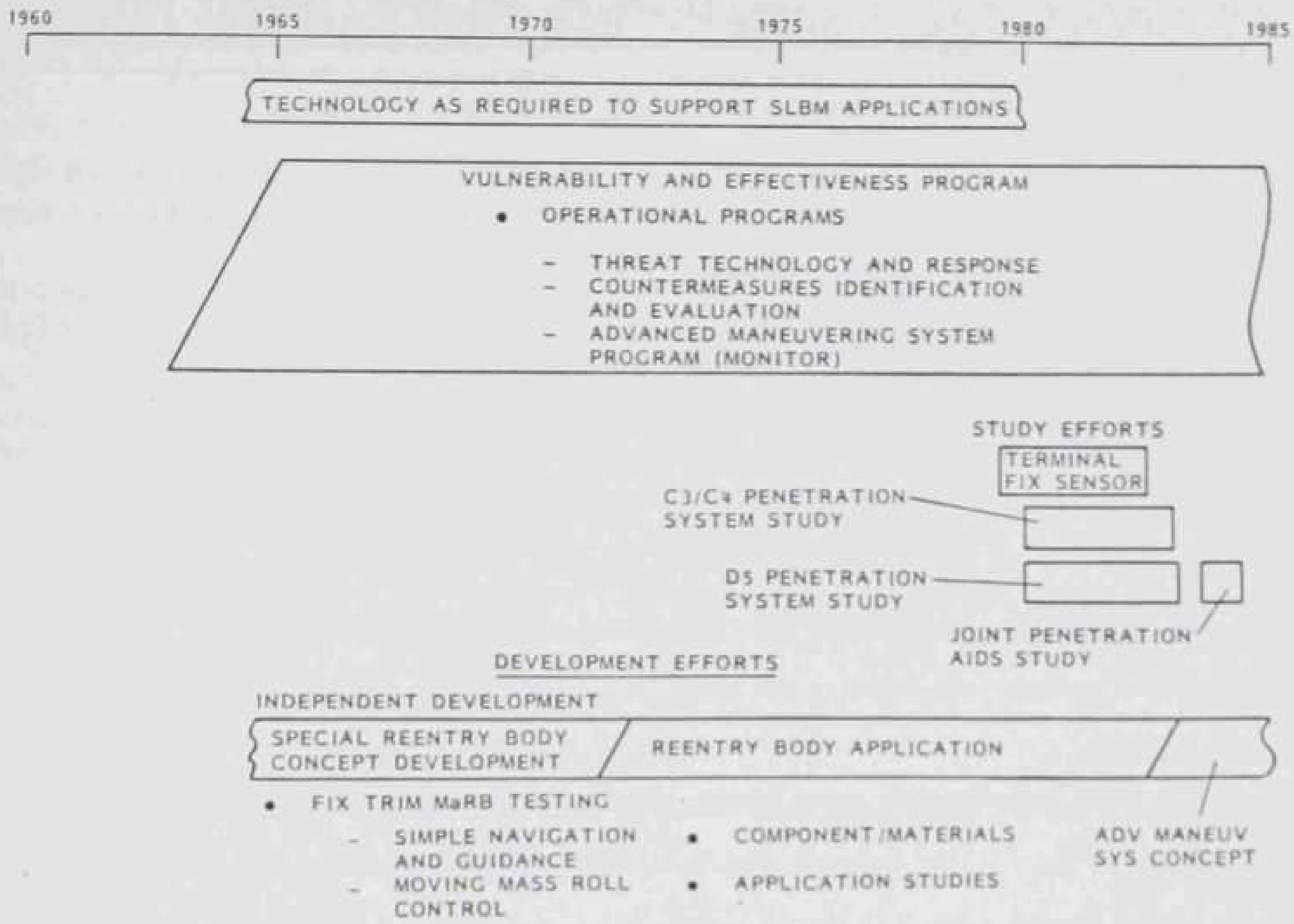
PENETRATION AIDS PROGRAMS

As mentioned earlier in this history report, there were various programs undertaken to increase the capability of the submarine-launched ballistic missile's reentry system to penetrate the evolving Soviet anti-ballistic missile defenses. These concepts, studies, developments, tests, etc., can be grouped under the generic term of Pen-Aids. LMSC, under contract to the SSPO, conducted various Pen-Aid studies and programs for the submarine-launched ballistic missile systems. In support of these, LMSC also continuously conducted its own Soviet anti-ballistic missile threat technologies studies and offered various Pen-Aid concepts.

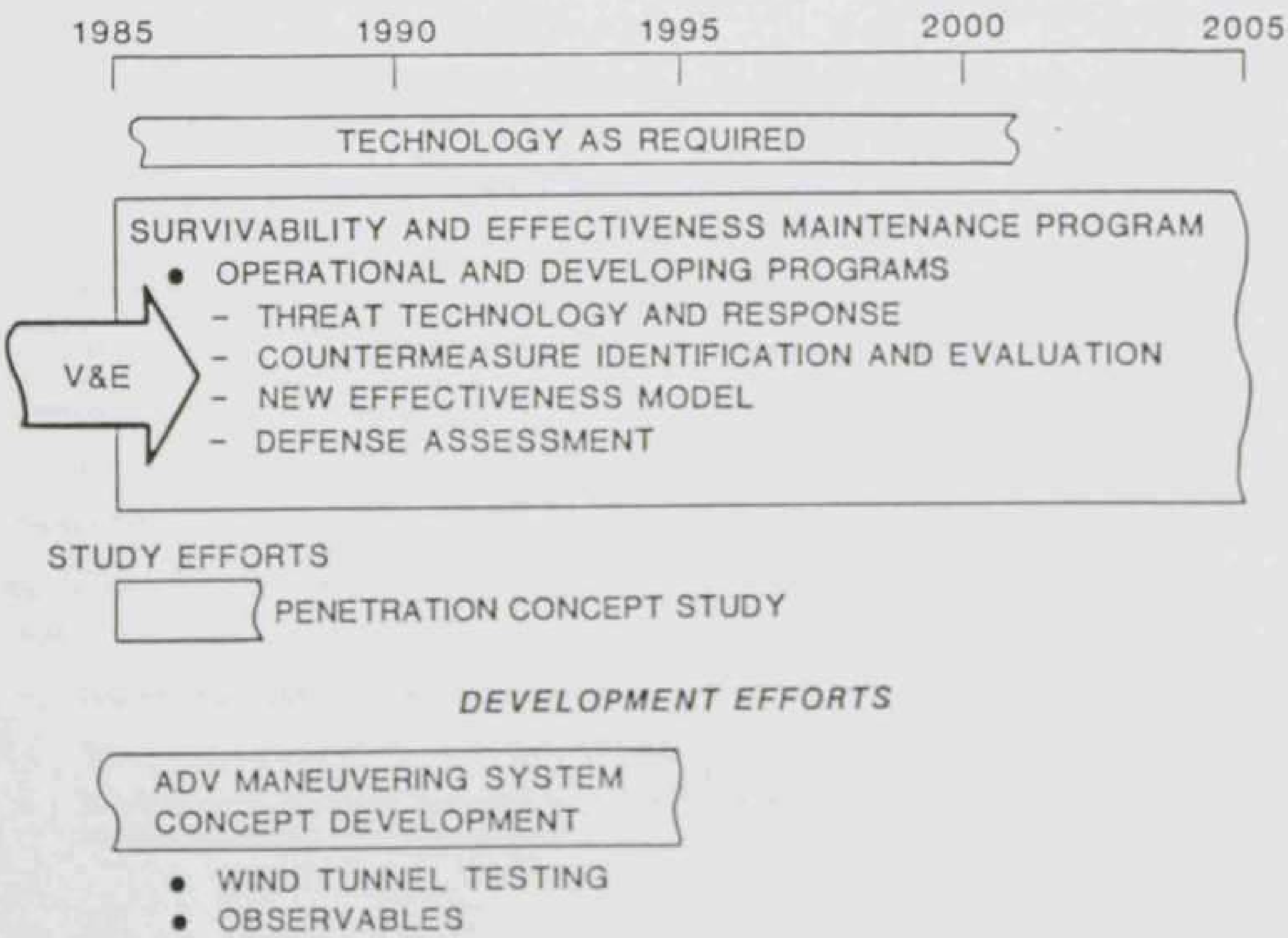
The following series of charts is an excerpt from a document "Overview of SLBM Penetration Programs" released by the author (J. P. McManus) on 13 October 1983 with updates in 1985. It covers the period 1960 to 1985 and relates to each of the missile programs through the present TRIDENT II (D5) baseline. Follow-on Pen-Aid studies for D5 and "Follow-on D5" are in progress. They have also been expanded to consider anti-ballistic missile threats during the launch/boost, mid-course, and in the terminal area. However, they are not included in this document since they are either classified or proprietary.



Submarine-Launched Ballistic Missile Penetration Programs



Threat Technology Developments



Threat Technology Plans

PX-1 (POLARIS A2)

- November 1961 - Contract go-ahead for PX-1 development to increase penetrability of Mk 1 reentry body
- Wind tunnel tests at CALAC and NSWC/WOL; RB deployment tests at Santa Cruz
- July 1962 - December 1962 - 12 PX-1 development flights (A2Ts); 7 successes - 5 no tests (missile anomalies); program of assessing PX-1 system performance considered a success
- System consisted of: decoys (simulate Mk 1 reentry body) mid-course chaff, early reentry electronic jammers; a system to control reentry body delta V and pitchover, away from the second stage rocket motors
- Flight test summary:

Decoys	Chaff	ECCM
PX-1D 120	PX-1C 15	PX-1E 30
	PX-1C 30	

- Production contract (Now 63-0063-c) for 221 kits July 1963 through July 1964
- Some deployed but later withdrawn as the threat did not emerge.

PX-1 System Description

- Mounted on a 4-1/2 in. long missile body extension ring - 6 decoys - 2 chaff packages
- Packages ejected after second separation when the reentry body sufficiently separated from equipment section
- Mounted in reentry body flare - 2 ECCM packages - 1 chaff package ejected after reentry body separation rocket is expended
- Support structure is jettisoned after penetration aids (Pen-Aids) ejected
- Penetrability of POLARIS A2 significantly increased by PX-1 system
- Provides threat down to 100 kft

PX-2 (POLARIS A3)

- April 1962 - Development of PX-2 began - to increase penetrability of Mk 2 reentry body
- Studies resulted in 6 decoys and 6 chaff packages as basic Pen-Aid system
  - Deployed from missile body forward base structure
  - ECM investigated but tradeoffs did not justify jammers
- 18 July 1963 - PX-2 flight tests commenced
  - 9 A3X flights from AMR
  - 3 A3X flights from PMR
- May 1965 - Tactical production of PX-2 initiated
- June 1965 - Production placed on standby pending appearance of exoatmosphere threat. Capability to deliver kits 18 months after go-ahead maintained

PX-2

- Flight test summary:

Decoys	
PX-2 dart	42
PX-2 vane	29
Twister (3H dorm)	14
Lightweight decoy (Mod 47)	1
Palloon erectable plate	3
Palloon Trinedral	3

Chaff	
PX-2	24
DFC	1
Exo-C	2
VC	2

- Penetration of the POLARIS A3 significantly enhanced by PX-2
- Concealment of the reentry body in exoatmosphere down to 200 kft
- Additional decoy targets down to 70 kft

ANTELOPE (IMPALA) POLARIS A3

Early 1965

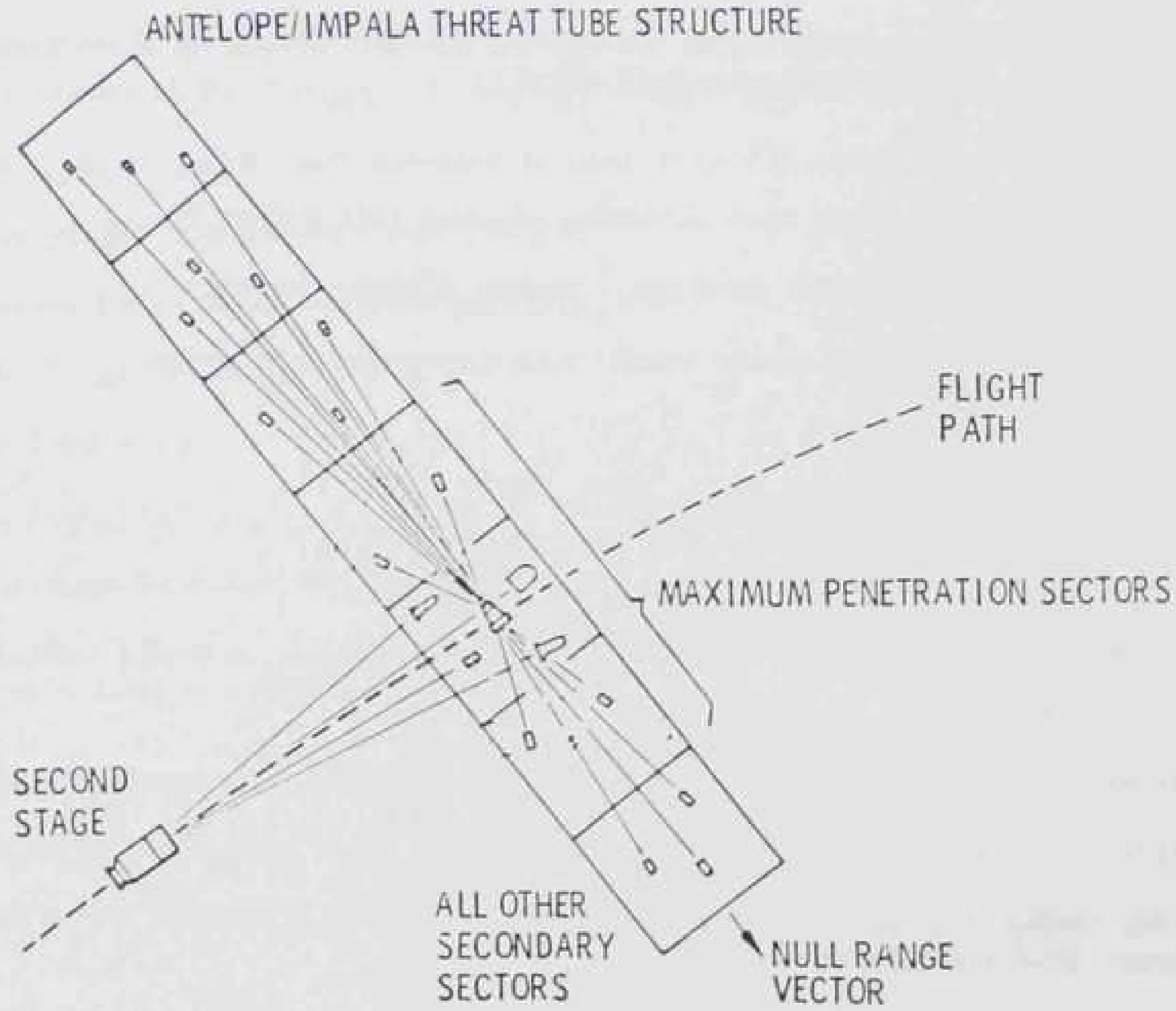
- U.S. Pen-X committee established new enemy area defense model Galosh type - 300 nm interceptor (NVC)
- POLARIS A3 with PX-2 little/no defense against VHF area defense
- Exo-PAC concept proposed
  - Replace Mk 2 reentry body with Pen-Aid carrier (chaff and ECM)
  - Used in conjunction with terminal defense
  - Has system for orienting the PAC unit and time sequencing release of payload components
- Pen-Aid carrier later retitled Mk 2 Mod 3 reentry body
  - Generates a highly-complex threat tube system structure consisting of multiple reentry bodies, simulated reentry bodies, each with its own chaff cloud
- July 1965
  - Mark-up - Mk 2 reentry body hardening program (Mk 2 Mod 2)
  - Exo-PAC - Combined with mark-up - became HEXO program
  - Topsy - On-going hardened missile body improvement program
- October 1965
  - HEXO and TOPSY program combined
- November 1965
  - Combined programs named ANTELOPE
- ANTELOPE objectives:
  - Improve probability of missile body and reentry body surviving nuclear environment in the launch area
  - Improve probability of reentry body surviving nuclear environment during exoatmospheric flight
  - Provide lofting capability, including MMOT to increase ANTELOPE threat system structure credibility and survivability

- IMPALA - originally part of the HEXO program - study for an advanced terminal defense penetration system
- After HEXO became part of ANTELOPE, study continued as a separate program IMPALA
- IMPALA extends ANTELOPE exoatmospheric threat to the target
  - Adds both small and large decoys to basic ANTELOPE chaff system
  - In addition to launching Pen-Aids from the Mk 2 Mod 3, hardware launch from front end of the missile body second stage
  - Threat tube formation divided into seven sectors
- September 1966 IMPALA incorporated into ANTELOPE program

THREAT TUBE SYSTEM STRUCTURES:

- Mk 2 Mod 3 reentry body (Pen-Aid carrier) ejected from missile body
- Mk 2 Mod 3 ejects modules into threat tube
  - Cylindrical - 125 nm long, 10 nm in diameter
  - Divided into equal sectors
- Original concepts - eight equal sector threat tube with specular reflector and chaff in each
- Concept changed - nine equal sector threat tube with specular reflector and chaff in each
- Threat tube changed to seven equal sector with incorporation of IMPALA

ANTELOPE/IMPALA THREAT TUBE STRUCTURE



- Flight test summary
  - 14 ANTELOPE development flights November 1966 - April 1968
    - 9 successes, 3 partials, 2 failures
  - 5 IMPALA hardware development flights March 1967 - February 1968
    - ATHENA vehicle at White Sands
    - All successful
- Hardened electrical cables, conduits and electronic packages plus lofting capability went into production and deployed in all POLARIS A3's (A3P ➤ A3T) October 1969

POLARIS B3 MISSILE

- Early 1963 advanced studies of a follow-on to the POLARIS A3 to:
  - Offset possible 1969 USSR high-performance antiballistic missile
  - Continue urban-industrial target coverage
  - Add hard point target capability
- July 1963 POLARIS B3 missile
  - Approximately 34.3 ft long versus 32.3 ft of A3
  - Approximately 74 in. diameter versus 54 in. of A3
  - Various reentry systems in keeping with penetrability requirements against targets of interest
- Five categories of reentry systems offered
  - Large single warhead
  - Multiple warhead
  - Aerodynamic maneuvering single warhead (B3H and KAYAK) (original Mk 500 concepts)
  - Boosted reentry vehicles (diver)
  - Ballistic delivery - low-altitude terminal dash (BOLA)
- B3D reentry system proposed
  - 3 reentry bodies
  - Chaff and decoy Pen-Aids plus possible ECM and RAM (radar absorber material)
  - Drums-shaped missile section containing guidance and controls (original bus concept)
- B3 study evolved in 1966 into the POSEIDON C3 program with bus and multiple reentry bodies

POSEIDON C3

1964 - 1967 Subsystem A (SSA) Study

- A study to enhance the penetration effectiveness of the POSEIDON C3 Mk 3 reentry body
- POSEIDON C3 missile under development was a two booster stage missile with a maneuverable equipment section and multiple reentry bodies (Mk 3)
- Optimum configuration of Pen-Aids was the module assembly concept
- One module replaces one Mk 3 reentry body
- A module contains either 7 decoys or 12 clutter clumps
- Various decoys in a module simulate the Mk 3 in either the exoatmospheric region, down to 200 kft, 150 kft, and 40 kft
- Clutter clumps prevent discrimination between Mk 3's and decoys

1969 Study Updated

- Three alternative payloads concepts to enhance POSEIDON penetration
  - Add SSA to the baseline C3 missile
  - Develop a maneuverable reentry body (MaRB) in lieu of Mk 3
  - Develop a multiple bus concept as an alternative to the single C3 bus

Pen-Aid Program (PAP) - 1971

- Study to evaluate alternate penetration option for C3 against the SA-2 and SA-5
- Options included
  - Modify Mk 3 jacket
  - Passive decoys
  - Simple MaRB (Jinker)
- Static RES measurement made of prototype concept - to confirm potential

Common SLBM Pen-Aids Study - 1978 (C3 and C4)

- Concept studies
  - Threat included ABMX-3
  - Common Pen-Aid systems for ballistic reentry bodies (BRBs) and MaRBs
  - Common Pen-Aid launcher for BRBs and MaRBs C3 and C4 or C4 only
  - Weapon system impact - development costs/schedule/risk
- Findings - no common decoy for Mk 3, Mk 4 and Mk 500. Common launcher devised

FBM Penetration Study - 1983 (C3, C4 and D5)

- Improvements in antiaircraft SA-X-12 may be carried over to a BMD mode
- Studies recently underway (July) addressing C3/Mk 3 and C4/Mk 4 plus D5
  - Identify defense and offense options
  - Identify options - evaluate weapon system impact and cost/schedule effectiveness to be completed by 31 October 1983

TRIDENT I (C4)

1971

- Mk 500 program initiated to provide a deterrent against potential proliferation or upgrade of Soviet defenses
- Began as a Development Program with Mk 4 RB but became an ADP due to the ABM treaty
- Mk 500 program was to develop a small evader MaRB and associated Pen-Aids system
- The program was to demonstrate MaRB and associated Pen-Aids system
- There were three phases to the program:

1971-1976 Evader 1976-1978 Improved Evader 1978-1982 Advanced Evader	Feasibility and Demonstration

- Readiness and maintenance status - availability 3 years after go-ahead

TRIDENT II (D5)

1980 - 1983

- Multiple RB configuration
- Improved Accuracy Program (IAP) features incorporated consideration of a large accurate evader (LAE) with Pen-Aids
  - Interface provisions being retained in D5 development
- Terminal Fix System (TFS) study
- Joint Navy (SSPO)/Air Force penetration study underway to evaluate penetration concept (common?) for U. S. ICBM/SLBM systems
- Studies conducted of follow-on MaRB for TRIDENT II (D5) - large accurate evader - and/or advanced maneuvering system (AMS) concepts

FBM Shorebase Weapon Facilities

There are four Naval facilities which are central to the FBM programs: POLARIS Missile Facility, Atlantic (POMFLANT), located in Charleston, South Carolina; Strategic Weapons Facility, Pacific (SWFPAC), located in Bangor, Washington; Strategic Weapons Facility, Atlantic (SWFLANT), located in King's Bay, Georgia; and the Naval Ordnance Test Unit (NOTU), located at the Eastern Space and Missile Center in Florida. These facilities supply missiles to the fleet and support the deployed submarines.

LMSC/MSD is the prime contractor providing services for the Missile Branch (SP-27) of SSPO at POMFLANT, SWFPAC, and SWFLANT. Other weapon system subcontractors also have personnel at these facilities, or are available on an "as needed" basis. In addition to complete missile processing, MSD provides self-administration, miscellaneous special services, field documentation, and major support in engineering, quality engineering, product assurance reliability, and operations support, and facilities engineering for TRIDENT and POSEIDON operations.

At the Eastern Space and Missile Center, through contractual coverage provided by SP-25, LMSC/MSD manages, operates, and maintains the Navy's test facility at the Eastern Space and Missile Center to support flight test programs. (The Eastern Space and Missile Center is an Air Force facility.) MSD also provides engineering, logistic, and personnel support to the fleet at Port Canaveral, as requested by the Commanding Officer of NOTU. The colloquial name of this test facility is the Eastern Test Range. There is also a Western Space and Missile Center (known as the Pacific Missile Range), also managed by the Air Force which provides support to FBM Operational Tests in the Pacific.

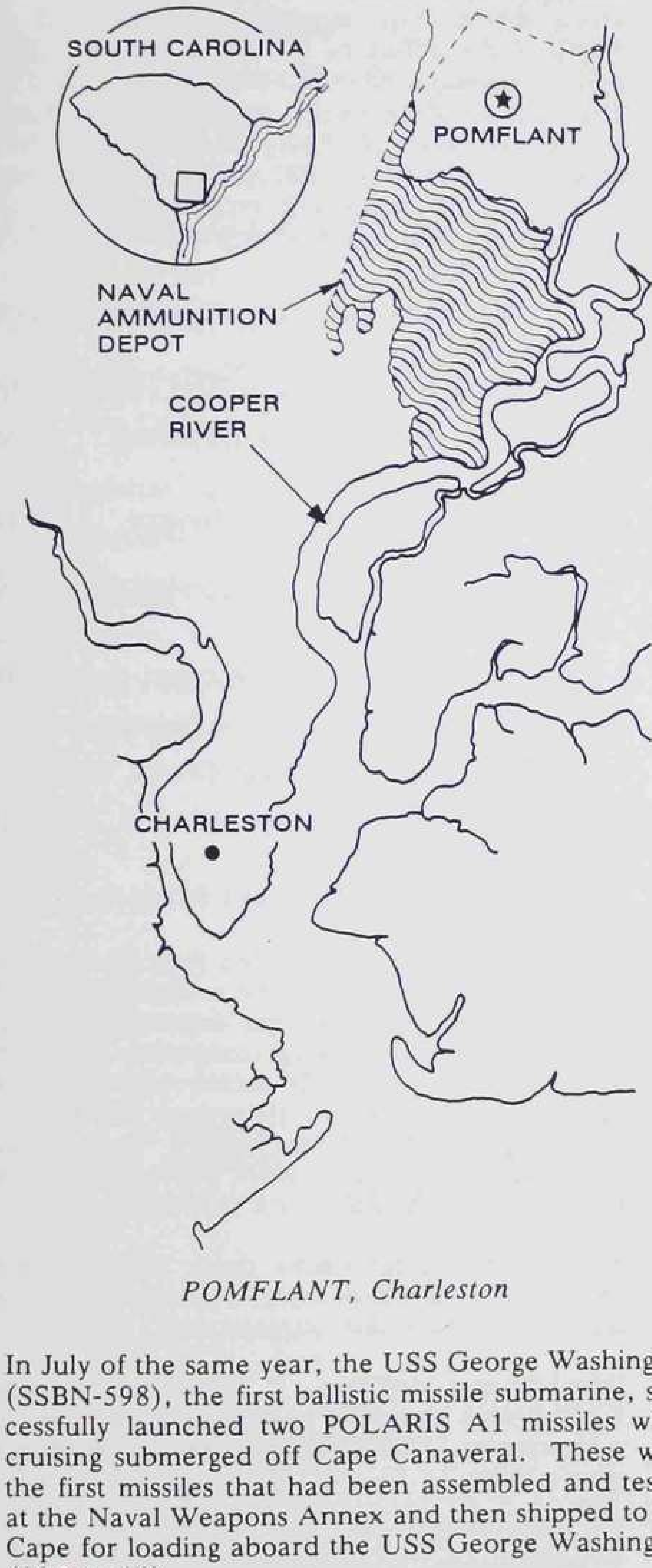
At POMFLANT, SWFPAC, and SWFLANT, the operations are basically the same. The missile structure (ES, I.S., etc.), along with most of the electronics packages, are manufactured at LMSC/MSD, Sunnyvale, California, and shipped to the facilities. Many of the other missile components (e.g., PBCS (valves manifold) and TVC systems) are delivered from vendors to LMSC/MSD and assembled there as subsystems, checked out, and shipped to the facilities along with the missile structure. The missile NF (Lockheed Corporation, Burbank, California) and the rocket motors are shipped direct from the subcontractors (e.g., Hercules, Thiokol, UTC, Aerojet) to the facilities. Other components of the missile (e.g., ordnance, batteries, guidance) are also shipped direct to the facilities. In the case of tactical RBs (warheads), LMSC/MSD manufactures the RB shell and release system. The DoE supplies the physics package and the DoD furnishes the fuzing system from its subcontractors, Sandia/Bendix. These RB components are assembled at a facility (PANTEX) near Albuquerque, New Mexico, and shipped to the facilities. At POMFLANT, SWFPAC, and SWFLANT, the missile components and RBs are received, assembled, checked out, and loaded on SSBNs or stored for future outloads. Fleet return missiles are received at these facilities disassembled, refurbished, or repaired as necessary, reassembled, checked out, and outloaded again or stored.

Initially in the program, most of the facility operations were performed by naval personnel or civil service personnel, supported by LMSC/MSD personnel. Since the late 1970's, the operation has become more of a GOCO (Government Owned Contractor Operated) operation with LMSC/MSD performing many of the functions.

With the advent of TRIDENT II (D5), the "factory has been extended to the facility." In the past, the missile's major components were bought off (DD250'd) by the Navy at LMSC/MSD or the major vendor's plant. They were thus government-owned, shipped to the facilities, and assembled. With D5, ownership does not transfer to the Navy at LMSC/MSD Sunnyvale. The components are shipped as "work-in-process" to the facility (SWFLANT) where MSD personnel assemble and check out the missile. It is at this point that the Navy "buys off" the complete missile (DD250'd), and it becomes government-owned material.

POLARIS Missile Facility, Atlantic (POMFLANT), Charleston, South Carolina

On 30 September 1958, the Office of the SECDEF approved construction of a POLARIS missile assembly facility near Charleston, South Carolina. Major components of the tactical POLARIS missile were to be shipped there, assembled, checked out, and outloaded on FBM submarines or stored for future outloading. The facility was to be on dormant government property near Charleston, South Carolina, some 17 miles up the Cooper River from the Atlantic Ocean. The largely undeveloped pine forest and marsh site had been an Army ordnance depot during World War II. The Navy acquired the 5,185 acre property in 1954, adding it to the adjacent Naval Ammunition Depot. Construction crews broke ground in December, only 4 months after site selection. ADM Raborn briefly viewed the Naval Weapons Annex, as it was called at the time, in July of 1959. Being on the Cooper River provided access to direct loading of missiles on SSBNs. Some 36 magazines built by the Army during the 1940's were modified and updated, and a large handling crane was installed at Pier Bravo of the Naval Ammunition Depot. The facility was known as the Naval Weapons Annex, a tenant of the Naval Ammunitiion Depot, Charleston, South Carolina. It was commissioned on 29 March 1960.



POMFLANT, Charleston

In July of the same year, the USS George Washington (SSBN-598), the first ballistic missile submarine, successfully launched two POLARIS A1 missiles while cruising submerged off Cape Canaveral. These were the first missiles that had been assembled and tested at the Naval Weapons Annex and then shipped to the Cape for loading aboard the USS George Washington (SSBN-598).

On 3 November 1960, the USS George Washington (SSBN-598) steamed into Charleston, South Carolina, and tied up at Naval Ammunition Depot's Pier Bravo. At 5:15 p.m. that afternoon, the first tactical POLARIS A1 missile was loaded aboard the USS George Washington (SSBN-598) "without complications." By 7 November 1960, all 16 missiles were in the submarine's launch tubes, and the crew had begun initial checks of their newly-acquired "birds."

As scheduled, the USS George Washington (SSBN-598) slipped from her berth about noon on 15 November 1960 and headed down the Cooper River channel to the Atlantic Ocean. The Naval Weapons Annex had passed its first boat-load test with flying colors.

Soon thereafter, the USS Patrick Henry (SSBN-599) arrived at the Naval Ammunition Depot, Charleston, South Carolina, pier and received its shipfill of tactical POLARIS A1 missiles during 17 – 30 December 1960. ADM Raborn was sufficiently impressed with the USS Patrick Henry's (SSBN-599) outload to send a "Well Done" to all hands of the Naval Weapons Annex, including its military contractor and civilian personnel."

During the next year, 1961, three additional submarines were outloaded.

In 1962, the Naval Weapons Annex acquired the capability to process POLARIS A2 missiles. The USS Ethan Allen (SSBN-608) deployed from Charleston, South Carolina, with the first submarine load of A2's on 26 June 1962. Three other submarines were outloaded with A2 missiles during the year.

In 1964, the expected heavy POLARIS A3 workload commenced. The Naval Weapons Annex acquired the capability to assemble and test POLARIS A3 missiles and outloaded 10 submarines, 8 with POLARIS A2 missiles and 2 with POLARIS A3 missiles. The USS Daniel Webster (SSBN-626) was the first submarine to carry the new and longer-range POLARIS A3, deploying from Charleston, South Carolina, on 28 September 1964. On 21 July 1964, the SECNAV changed the name of the facility from Naval Weapons Annex to the POLARIS Missile Facility Atlantic (POMFLANT).

During 1968, POMFLANT began to acquire the additional buildings and equipment to process the new POSEIDON C3 missile. POMFLANT began processing the POSEIDON PEM in 1970. The PEMs were loaded aboard the backfitted USS James Madison (SSBN-627) and USS Daniel Boone (SSBN-629) for test firing off Cape Canaveral. Tactical POSEIDON missile production began shortly thereafter. The USS Madison deployed from Charleston, South Carolina, with the first POSEIDON C3 shipfill on 31 March 1971.

During 1974, the final POLARIS A3 buildup at POMFLANT was completed on 30 July, and the final POLARIS A2 offloaded on 20 September. In 1975, contractor (LMSC) personnel began missile processing in Missile Assembly and Packaging Building No.

1. It was also in 1975 that conversion of the facility to process TRIDENT I missiles got underway.

In August of 1977, the Increased Contractor Participation contract was signed, and the contractor assumed production work in various production buildings on 1 December 1977.

Missile assembly and checkout of TRIDENT I's began in December 1978 with the first TRIDENT I PEM. The missile was outloaded aboard the USS Francis Scott Key (SSBN-657) on 20 February 1979. After DASO operations, the Francis Scott Key (SSBN-657) deployed on 20 October 1979 with the first shipfill of TRIDENT I tactical missiles.

During recent years, POMFLANT has established a pattern of sending out more than 150 TRIDENT C4 or POSEIDON C3 missiles each year, varying considerably with fleet needs. DASOs, outloads, and other fleet operations have been supported, including shipments to Holy Loch, King's Bay, and other Charleston area commands. Receipt of missiles from the fleet, disassembly, refurbishment and functional tests continued as required to support fleet needs.

During its years of service, POMFLANT has cycled missiles through assembly and test well over 4,000 times. It remains the only facility at which all five generations of FBM missiles have been processed. It has had all the FIRSTS and has always met fleet requirements.

It should be noted here that the POMFLANT facility provided the initial outload of a submarine. After a submarine completed its patrol, it returned to an assigned refit site for crew exchanges, supplies, etc. Each refit site had a submarine tender assigned to provide services. The original sites in the Atlantic were site No. 1 at Holy Loch, Scotland (9 March 1961); site No. 2 at Rota, Spain (24 February 1964); and Site No. 4 at Charleston, South Carolina (28 July 1965) (a few miles down the Cooper River from POMFLANT). A site No. 3 was established on December 1964 in the Pacific at Apra Harbor, Guam, to service the POLARIS SSBNs. The original SSBNs in the Pacific were outloaded with POLARIS A3 at POMFLANT. The USS Daniel Boone (SSBN-629) became the first of these SSBNs assigned to the Pacific fleet on 21 August 1964, and began the first Pacific operational patrol on 25 December 1964. The USS Proteus (AS-19) was the original tender assigned at Guam. It was also the first tender assigned at Holy Loch and at Rota. It was not until April 1965 that a Pacific SSBN was outloaded at POMFPAC, Bangor, Washington.

ULMS Refit Concept — Strategic Weapons Facility

The IDA 1967 STRAT-X Report, besides suggesting a new ULMS submarine and missile, also suggested concepts for a ULMS Refit Complex. In order to assess the concept feasibility, the Director of the SSPO of the Office of the CNM initiated, directed, and coordinated the ULMS Refit Complex Study. The purpose of the study, started in November 1970, was to determine feasibility, magnitude of the complex, land, personnel, and dollar resources required as well as to evaluate and recommend Atlantic and Pacific sites. The following organizations provide support to this study:

a. Naval Ordnance System Command Headquarters

b. Naval Ship System Command Headquarters

c. Naval Facilities Engineering Command Headquarters

d. Naval Electronic Systems Command Headquarters

e. Fleet Missile Analysis and Evaluation Group, Corona

f. Naval Supply System Command Headquarters

g. Missile Evaluation Center, Pomona

h. Naval Underwater Sound Center, Newport

i. Naval Personnel Research and Development Laboratory

j. Armed Services Explosive Safety Board.

The primary goal of the ULMS Refit Complex was to improve the utilization (patrol availability) rate of the SSBNs. The utilization rate depended on the refit complex capabilities and a compatible SSBN design. The location of the refit facility plus missile range capability determines the percentage of "ready" missiles in a prompt response mode. The new ULMS extended-range missiles would provide this capability from the time the SSBN left CONUS ports.

The complex would have three major operational areas: an SSBN refit area, a weapons area, and a training and personnel support area.

Initial 87 sites located on U.S. territory (Atlantic and Pacific) were identified as candidate locations for the refit complex. The evaluation reduced the number of sites to 17:

1. Machias Bay, Maine
2. Breakwater Harbor, Delaware
3. Yorktown, Virginia
4. Charleston, South Carolina
5. Roosevelt Roads, Puerto Rico
6. Bangor, Washington

7. Humboldt Bay, California
8. Savannah River, Georgia
9. King's Bay, Georgia
10. St. John's River, Florida
11. Mayport, Florida
12. Cape Kennedy, Florida
13. Pensacola Bay, Florida
14. Mobile Bay, Alabama
15. Pascagoula, Mississippi
16. Point Arguello, California
17. New Orleans, Louisiana.

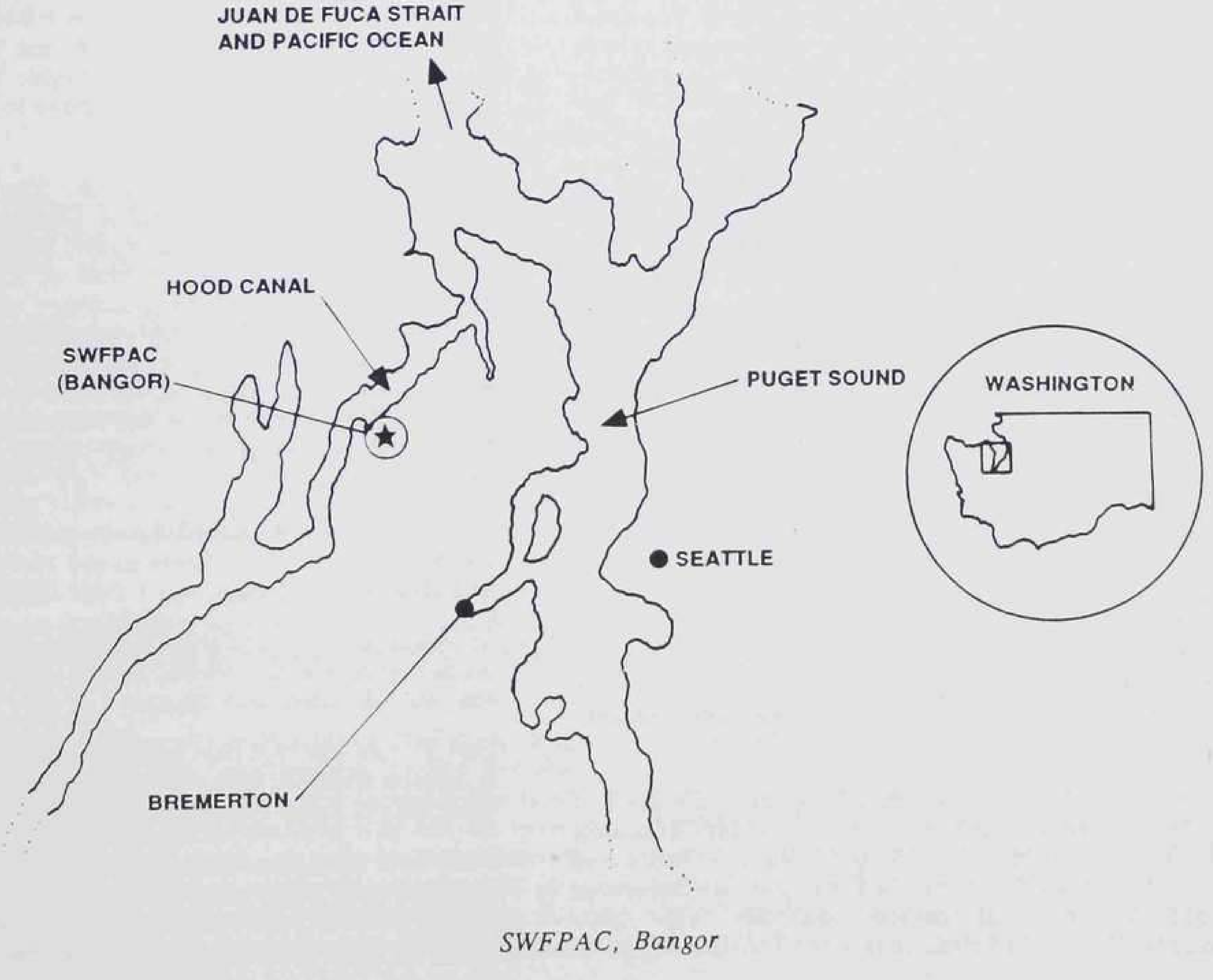
This number was then reduced to 5:

1. Yorktown, Virginia
2. Charleston, South Carolina
3. Bangor, Washington
4. King's Bay, Georgia
5. Cape Kennedy, Florida.

Navy plans called for initial deployment of the new TRIDENT submarine to be in the Pacific. Bangor, Washington, was announced on 16 February 1973 as the Pacific site for the ULMS Refit Concept. A candidate Atlantic site — King's Bay, Georgia — was later selected by the Navy in May 1979 as its preferred Atlantic ULMS Refit site. Following environmental impact studies, in October 1980, the SECNAV announced that King's Bay would become the Atlantic home for the new OHIO-class submarines.

Strategic Weapons Facility, Pacific (SWFPAC), Bangor, Washington

Navy plans called for the POLARIS FBM submarines to be operating in the Pacific. With this in mind, the DoD announced, on 23 April 1962, the selection of various POLARIS support facilities in the Pacific. Puget Sound Naval Shipyard at Bremerton, Washington, was selected as the FBM submarine overhaul facility; the Naval Ammunition Depot at Bangor, Washington, was selected for the POLARIS missile assembly facility; Pearl Harbor, Hawaii, was chosen as the location of the crew training facility. Construction of the $12.5 million facility at Bangor began in March 1963. On 1 September 1963, the missile assembly facility was established in a development status and, on 11 September 1964, POLARIS Missile Facility,



SWFPAC, Bangor

Pacific (POMFPAC) was commissioned at the Naval Ammunition Depot, Bangor, Washington. Bangor is located on the Kitsap Peninsula on the shores of Hood Canal. The base included 7,676 acres of land, 5,000 of which are wooded. Bangor is the natural home for a deer herd, several bears, and numerous other wildlife. The Olympic Mountains provide a scenic backdrop for the base.

Of the original personnel assigned to POMFPAC, 36 are still onboard, of which 20 are LMSC employees.

POMFPAC made its first tactical outload of POLARIS A3 missiles to the USS Stonewall Jackson (SSBN-634) on 26 March 1965, and the submarine departed on 9 April 1965 to commence operational patrol.

POMFPAC began converting tactical POLARIS (A3's) to the ANTELOPE (A3T) configuration in August 1970 and completed the ANTELOPE Exchanges Program in the Pacific in February 1972.

It was on 16 February 1973 that the SECNAV announced the selection of POMFPAC, Bangor, as the initial base for the new TRIDENT SSBN. The officer in charge of construction (Bangor) was established on 4 September 1973, and the Final Environmental Impact Statement (FEIS) for Bangor was approved on 26 December 1973. Besides the strategic missile processing facility, the Bangor shore activity would include a submarine base (SUBASE), a TRIDENT Refit Facility (TRIREFAC), and a TRIDENT Training Facility (TRITRAFAC). Construction started at Bangor on 15 October 1974, and it was in 1974 that the designation of POMFPAC was changed to Strategic Weapons Facility, Pacific (SWFPAC).

It was also on 19 August 1974 that LMSC was awarded the TRIDENT I (C4) and OSDP Contract. On 17 January 1977, the decision was made for production go-ahead on the TRIDENT I (C4). Because of an increasing workload, SWFPAC moved into an "Increased Contractor Participation" mode in 1977. LMSC was awarded a contract for A3 processing support in the calibration operations and various maintenance support buildings.

The Naval SUBASE was activated in a developmental-limited operational status on 1 February 1977. However, full formal activation of the SUBASE, along with activation of the TRITRAFAC and the TRIREFAC, was delayed until 1 July 1981.

SWFPAC commenced processing of TRIDENT I (C4) missiles in July 1980. Its first C4 DASO missile was airlifted from SWFPAC to the Eastern Space and Missile Center (Eastern Test Range) in December 1981 for eventual outload on the USS Ohio (SSBN-726). SWFPAC outloaded the USS Ohio in September 1982 with TRIDENT I (C4) missiles, and it deployed on patrol in the Pacific on 1 October 1982.

It was during this time frame, 1980 – 81, that POLARIS A3 missiles were being phased out of the Pacific. The last A3 tactical offload from the USS Robert E. Lee (SSBN-601) was completed by SWFPAC in February 1982.

Since the first TRIDENT I (C4) deployment, seven additional Ohio-class TRIDENT submarines have been outloaded at SWFPAC and deployed in the Pacific. The final outload was in September 1987.

SWFLANT, King's Bay, Georgia

A Treaty of Friendship and Cooperation was being drafted with Spain in 1976. It would require withdrawal of Submarine Squadron Sixteen from Rota, Spain, by July 1979. As a result, the CNO ordered, in 1976, a study to select a new site for relocating the SSBN tender from Rota to the East Coast. A site selection steering group evaluated sites along the Atlantic and Gulf coasts.

On 30 November 1976, the SECNAV announced that King's Bay, Georgia, has been identified for further study as the preferred alternative location for the possible construction of an East Coast FBM Tender refit site. It was on 26 January 1978 that the SECNAV announced that King's Bay, Georgia, would be the new location of the submarine tender to support Submarine Squadron Sixteen.

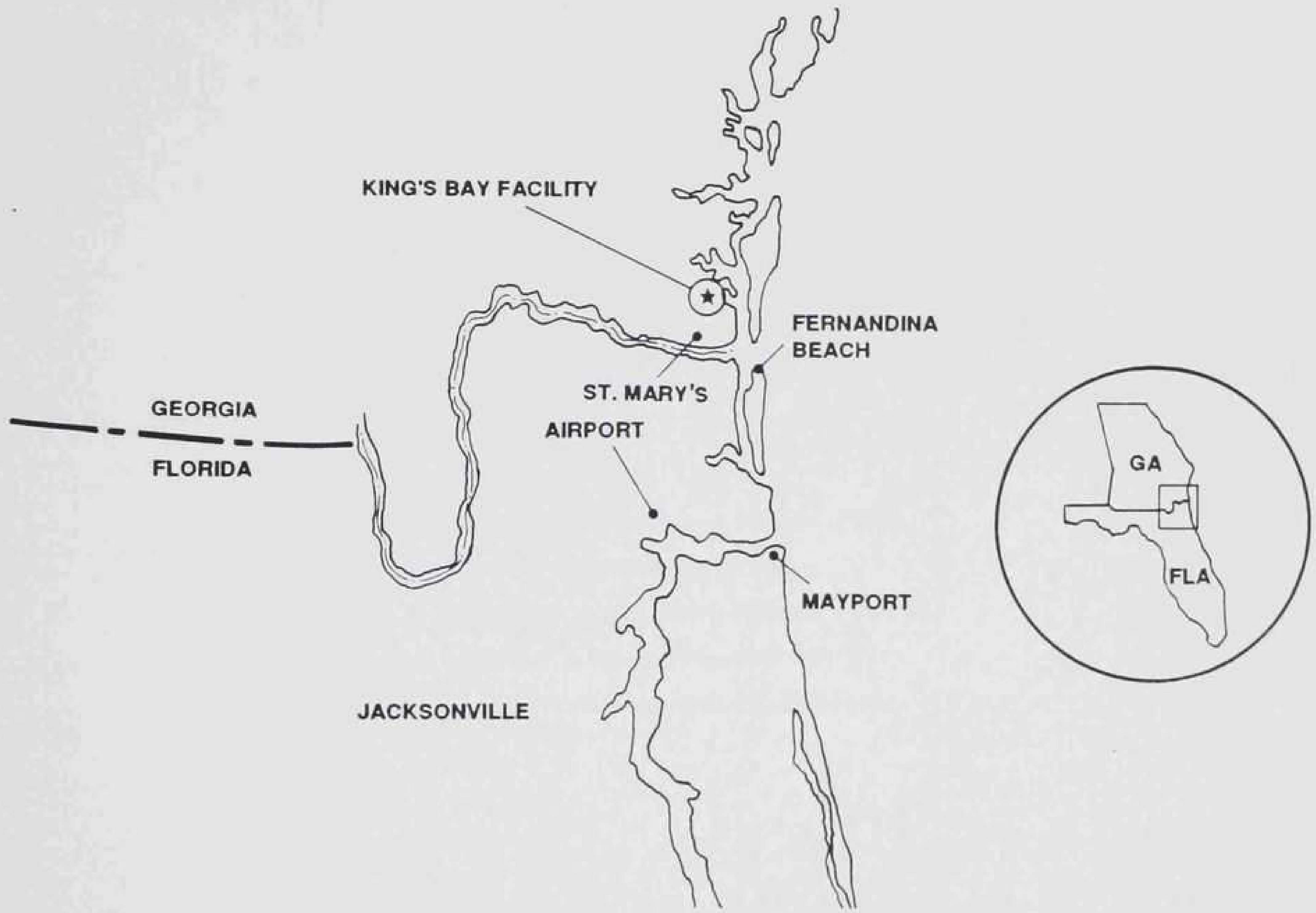
King's Bay, Georgia, is near St. Mary's, Camden County, Georgia, on an arm of Cumberland Sound, 35 – 40 miles north of Jacksonville, Florida. In 1954, the Army began to acquire land at King's Bay, on which it planned to build a military ocean terminal which would be used to ship ammunition in the event of a national emergency. Construction activity began in 1956 and was completed in 1958 at a cost of $11 million. Because there was not immediate operational need for the installation, it was placed in an inactive ready status.

Preparations were started for an orderly transfer of the property from the Army to the Navy, and the actual transfer took place on 1 July 1978.

Throughout the remainder of 1978 and into 1979, preparations for the arrival of the submarine squadron went forward with haste.

On 2 July 1979, the commander of Submarine Squadron Sixteen, embarked in the submarine tender USS Simon Lake (AS-33), arrived at King's Bay.

Four days later, the USS James Monroe (SSBN-622) entered King's Bay and moored alongside the USS Simon Lake's (AS-33) starboard side to begin a routine refit in preparation for another deterrent patrol.



SWFLANT, King's Bay

It was during this time that the need arose for a TRIDENT submarine facility in the Atlantic, similar to SWFPAC at Bangor, Washington.

In May 1979, the SSBN tender refit site at King's Bay was selected by the Navy as its preferred site for an East Coast strategic SUBASE to support TRIDENT and future generations of strategic submarines. Following environmental impact studies, in October 1980, SECNAV Edward Hidalgo announced the decision: King's Bay would become the Atlantic home for the new Ohio-class submarines.

On 1 April 1982, the title of the base was changed from Naval Submarine Support Base to Naval Submarine Base to reflect the growing significance of King's Bay.

Facilities at the base will enable King's Bay to serve as a homeport, refit site, and training facility for the Navy people that will operate and maintain the next generation of strategic submarines that will be here. The original facilities here, to refit between patrols SSBNs which were homeported elsewhere, cost approximately $125 million. The TRIDENT basing decision touched off a building project of vastly-larger magnitude. Through the 1980's, the Navy will spend more than $1.7 billion in the military construction effort alone.

Besides being a SUBASE, King's Bay will have three tenant commands:

1. TRIREFAC will provide support for the new submarines similar to that provided by today's submarine tender
2. TRITRAFAC for new submarine crews and provide refresher or advanced training to personnel during their off-crew periods between patrols
3. SWFLANT responsible for assembling, maintaining, and storing TRIDENT II (D5) missiles.

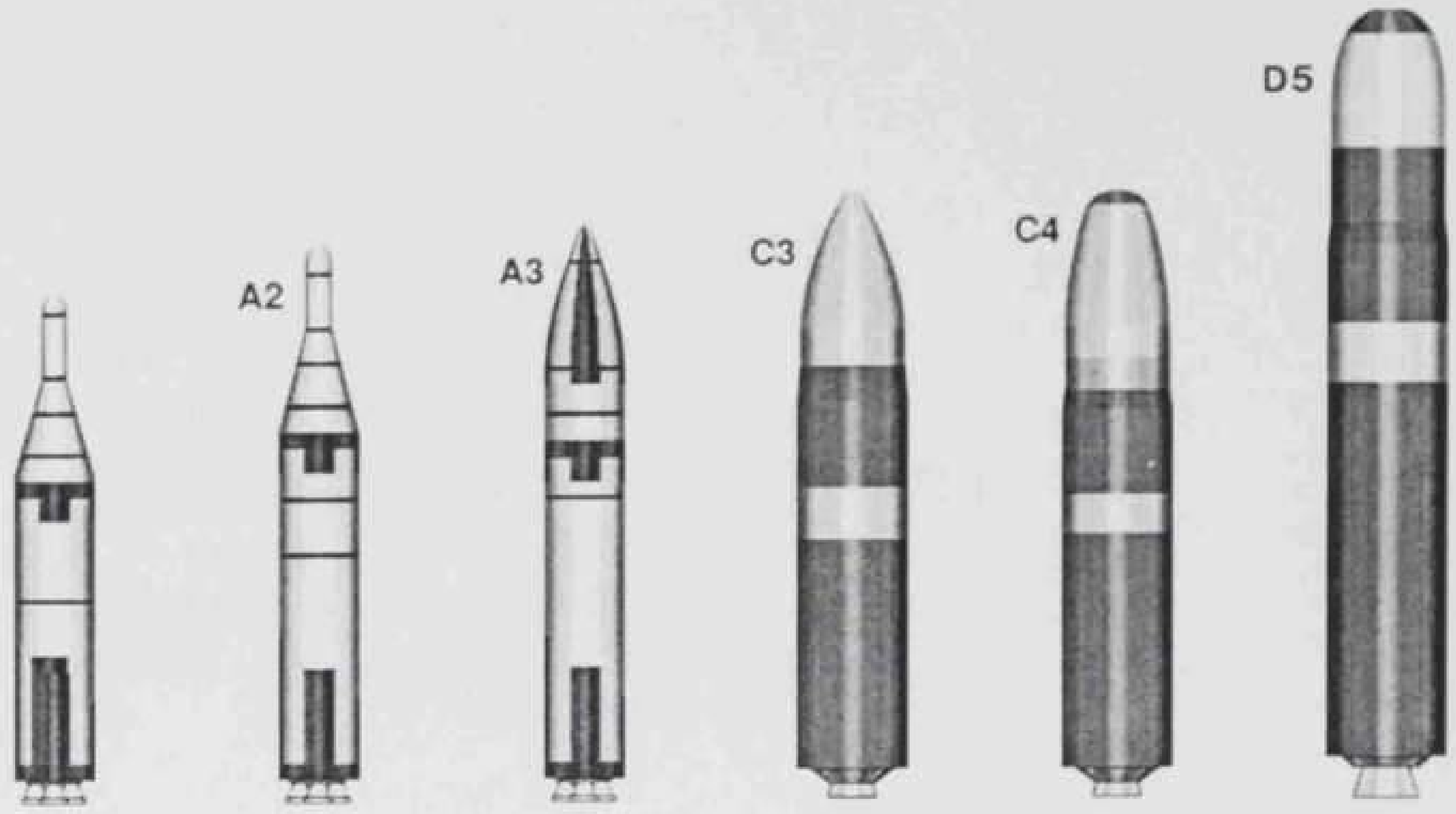
With the disestablishment of PM-2, the responsibility for acquisition of Naval SUBASE, King's Bay, was transferred to the SSPO on 30 June 1983.

SWFLANT's schedule calls for processing of TRIDENT II (D5) missiles to support PEM and DASO operations in early/mid-1989 and eventual outload of TRIDENT II (D5) tactical missiles on the USS Tennessee (SSBN-734) for deployment by the end of 1989.

FBM WEAPON SYSTEM SUMMARY

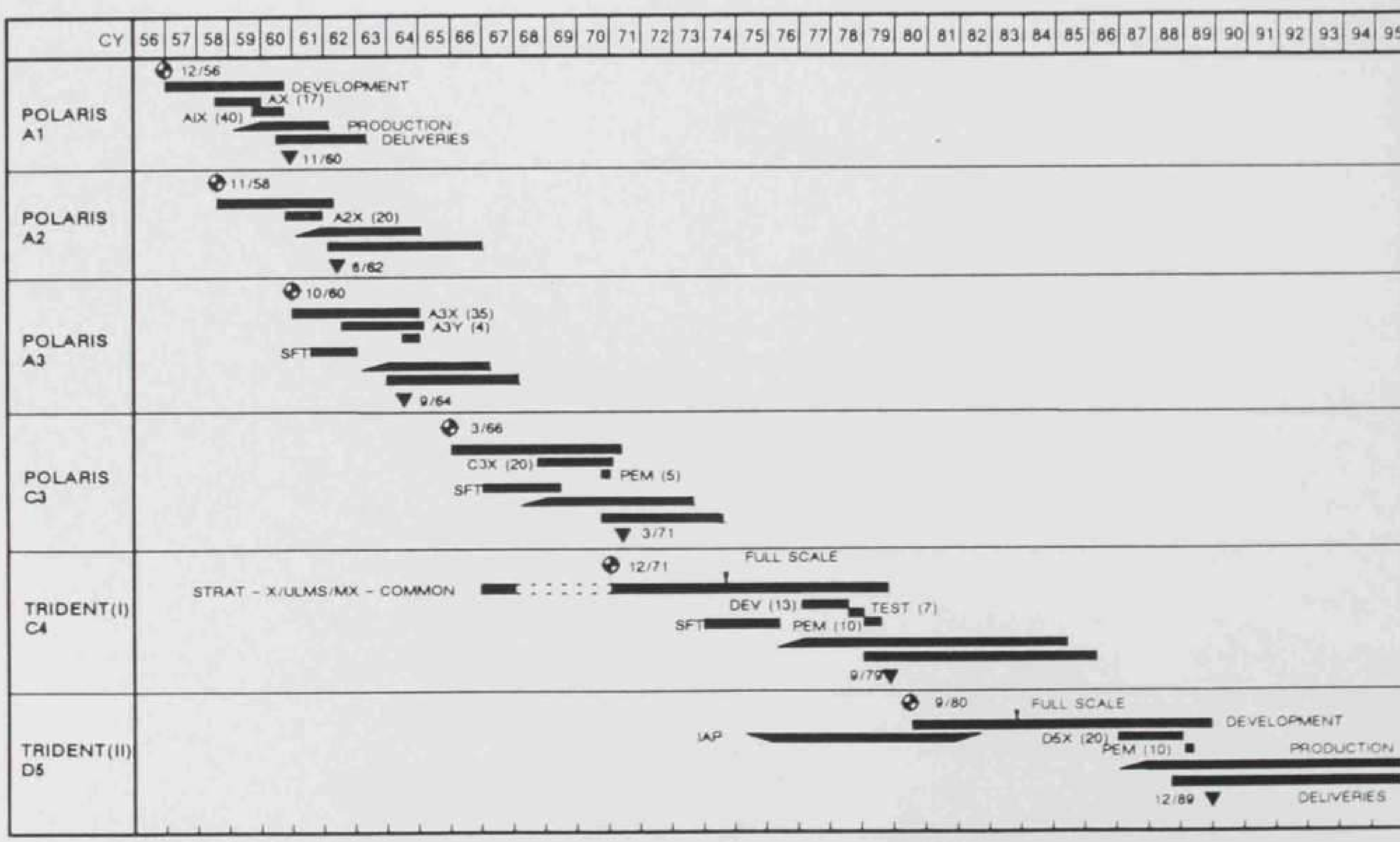
This section provides a brief historical summary of the scope of the FBM Weapon System. It consists of a series of charts covering:

1. The Strategic Missiles
   a. Program Schedules and Missile Facts
2. The Strategic Submarines (SSBNs)
   a. Comparisons and Deployments
3. The Strategic Systems Programs (Office)
   a. Organizations/Management Philosophy (No Change Policy).

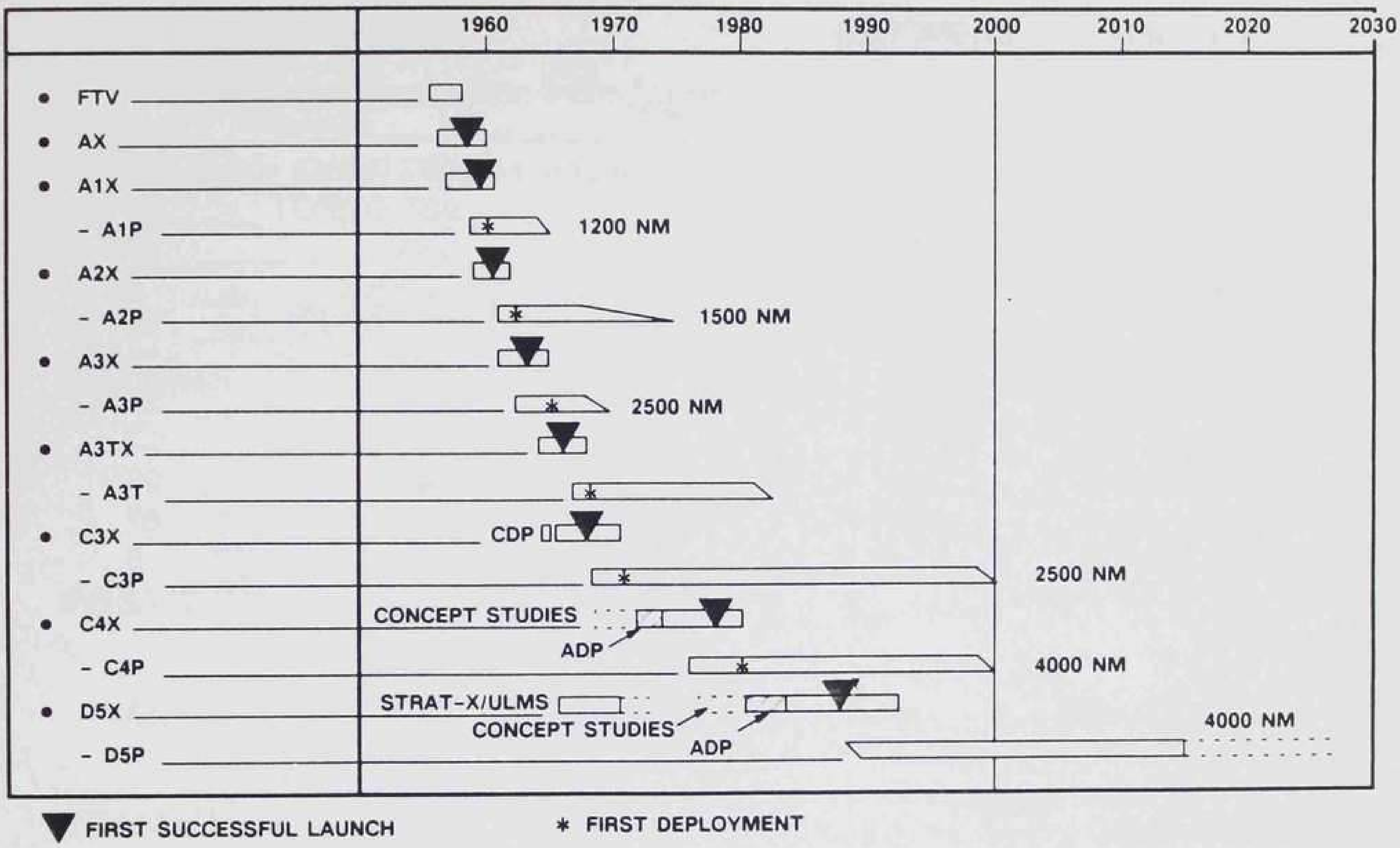


DEPLOYED	1960	1962	1964	1971	1979	1989
LENGTH (FT)	28.5	31.0	32.3	34.0	34.0	44.6
DIAMETER (IN)	54	54	54	74	74	-83
WEIGHT (LB)	28,000	32,500	35,700	64,000	73,000	130,000
RANGE (NM)	1200	1500	2500	2500	4000	4000

Fleet Ballistic Missile



Missile Development Programs



Fleet Ballistic Missile Programs

- POLARIS A1 DEPLOYED NOVEMBER 1960 RETIRED OCTOBER 1965
- POLARIS A2 DEPLOYED JUNE 1962 RETIRED JUNE 1974
- POLARIS A3 DEPLOYED SEPTEMBER 1964 RETIRED FEBRUARY 1982
- POLARIS C3 DEPLOYED MARCH 1971
- TOTAL OF 41 FBM SUBMARINES (SSBNs) AT THE BEGINNING OF 1979

  10 - POLARIS A3's IN THE PACIFIC
  31 - POSEIDONS C3's IN THE ATLANTIC

- SSBN TENDER WITHDRAWN FROM ROTA, SPAIN, STATIONED AT KINGS BAY, GA. MID - 1979
- POMFLANT FACILITY READY TO PROCESS TRIDENT MISSILES IN LATE 1978
- TRIDENT I (C4) DEPLOYED IN BACKFIT SUBMARINE IN THE ATLANTIC IN OCTOBER 1979
- SWFPAC FACILITY READY TO PROCESS TRIDENT MISSILES IN MID 1980
- TRIDENT SUBMARINE (T-01) DEPLOYED WITH C4s IN THE PACIFIC 1 OCTOBER 1982
- POSEIDON (C3) SSBNs OFFLOADED AND DISMANTLED - ARMS CONTROL LIMITS SSBN-635 IN 1985; -623 AND -636 IN 1986 AND -619 IN 1988

Fleet Ballistic Missile (FBM) Weapon System

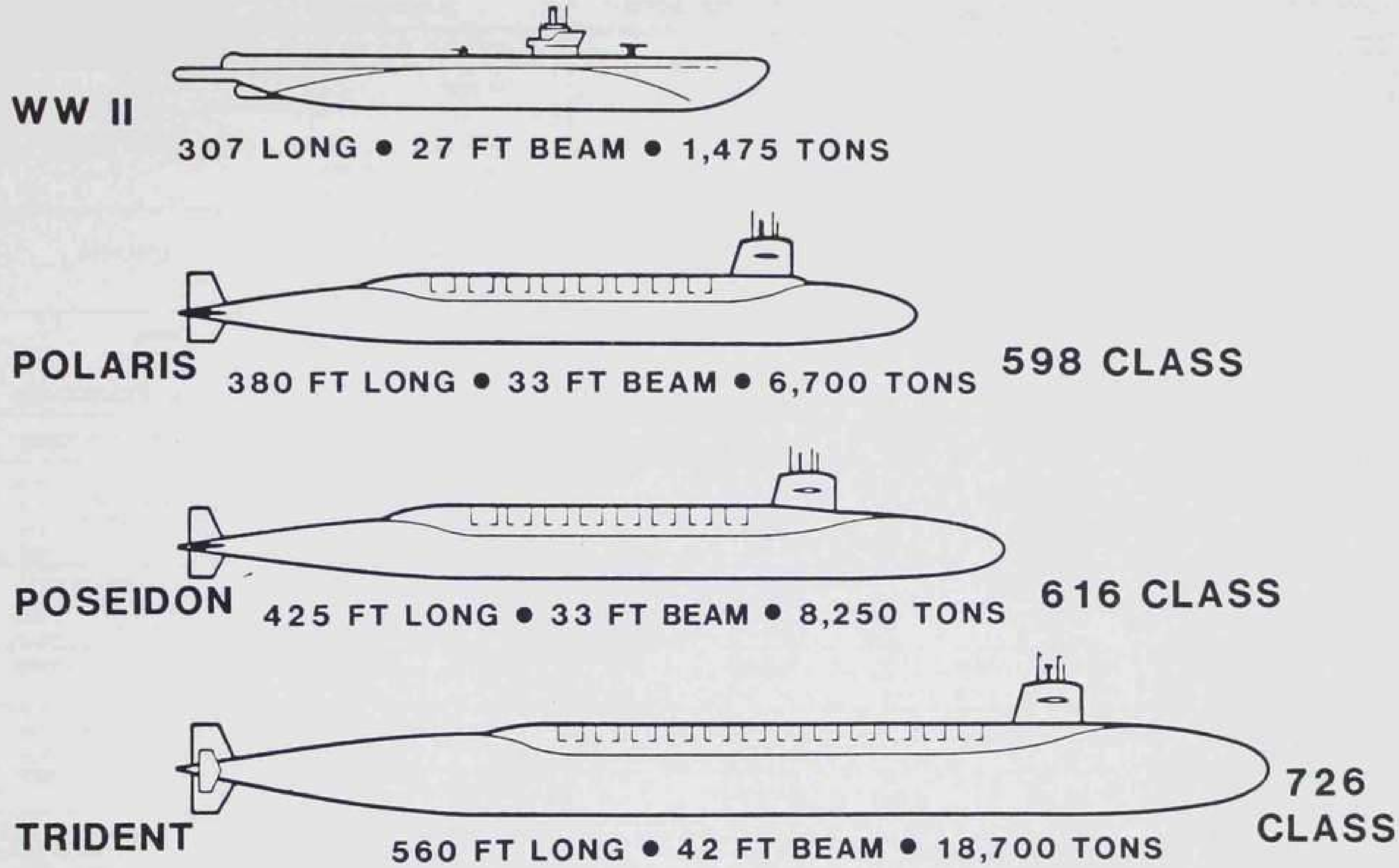
MODEL	LAUNCHED	MODEL	LAUNCHED
US			
AX	17	A3T DASO	16
A1X	42	A3T OT/FOT	89
A1P DASO	36	C3X	20
AIP OT/FOT	23	C3 PEM	5
A2X	28	C3E DASO	58
A2P DASO	60	C3P OT/FOT	176
A2P OT/FOT	112	C4X	18
A3X	41	C4 PEM	7
A3P DASO	69	C4T DASO	28
A3P OT/FOT	52	C4T OT/FOT	87
A3TX/Y	14	D5X	8
UK			
A3P DASO	14	A3TK DASO	13
A3TK PAD	11	A3TK CAF	4
A3TK PS	2	A3R PEM	4

AS OF DEC '87

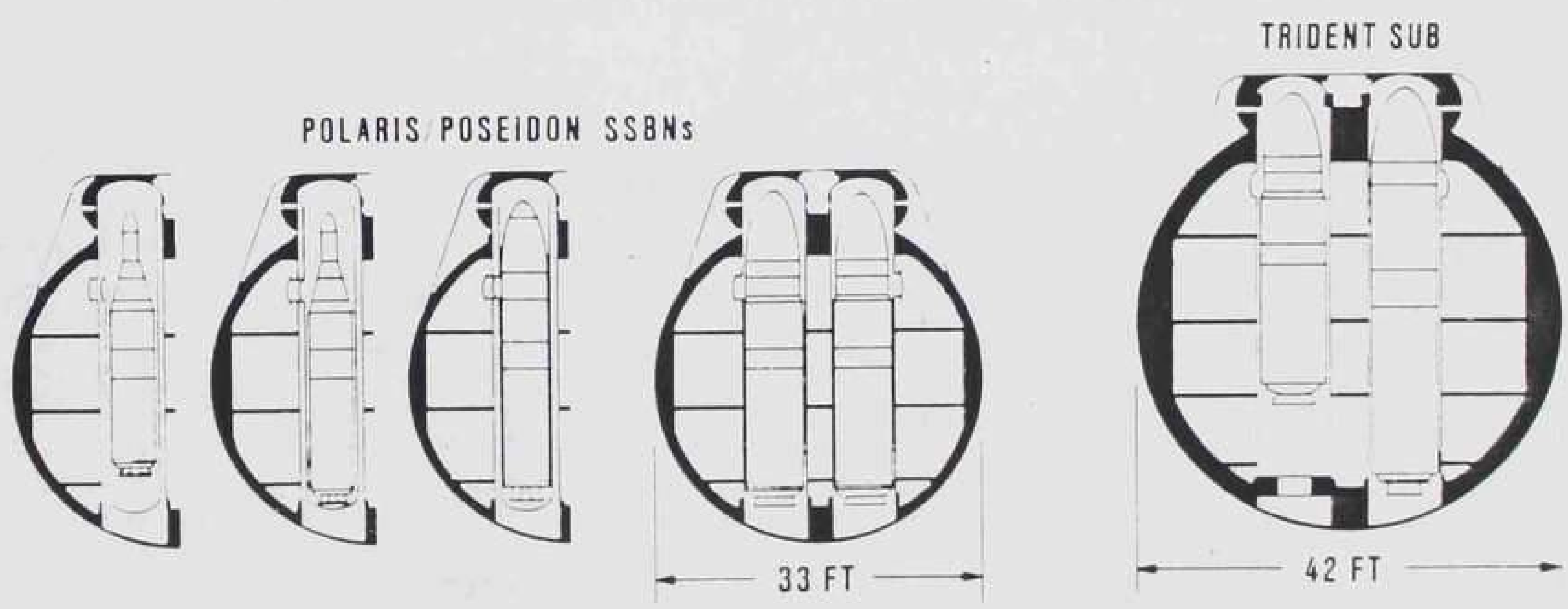
Flight Test

	A/AI	A2	A3	C3	C4	D5
R&D FUNDING	DEC 1956/NOV 1957	NOV 1958	OCT 1960	FEB 1965 (CDP) MAR 1966	JUL 1967 (STRAT-X) NOV 1971 (ADP)	1976 (CONCEPTS) OCT 1980 (ADP)
FIRST "X" TEST/FLT	SEP 1958/SEP 1959	NOV 1960	AUG 1962	AUG 1968	JAN 1977	JAN 1987
FIRST PROD AUTHORIZED	JUL 1959	DEC 1960	FEB 1963	1968	LL 1976 MAR 1977	LL OCT 1986 MAR 1987
FIRST PROD DELIVERED	APR 1960	JAN 1962	FEB 1964	MAY 1970	JAN 1979	NOV 1988 (SV) MAY 1989 (LANT)
IOC	15 NOV 1960	26 JUN 1962	23 SEP 1964	31 MAR 1971	20 OCT 1979 (SSBN-657) 1 OCT 1982 (SSBN-726)	DEC 1989
LAST PROD DELIVERED	NOV 1961	JUN 1964	MAY 1967	OCT 1975	JAN 1986	2001
TOTAL PROD MISSILES	173	350	666 US 79UK 745	614 5 PEM	570 7 PEM	871
TOTAL RVs (PROD (?DEVEL)	Mk 1 491 (600)		Mk 3 2067 (2300)	Mk 3 6106 (6300)	Mk 4 4187 (4327)	Mk 4 1404 Mk 5 3743 5147 UK-Mk 4 946
RETIRED	14 OCT 1965	9 JUN 1974	25 FEB 1982	DEPLOYED	DEPLOYED	TBD
YEAR OF SIGNIF MOD			A3T TEST 1966-1977 PROD MAY 1968			
			A3R[2] MAR 1966 MAR 1967	C3R[2]/POMP MAR 1973 APR 1974		
MIRV STARTED WITH C3	MaRV IR&D SINCE 1962			Mk 500 PROGRAM 1971-1982		

FBM Missiles



Submarine Comparison



	Polaris/Poseidon A1	A2	A3	C3	C4	Trident C4	D5
DATE DEPLOYED	1960	1962	1964	1971	1979	1979	1989
RANGE (NM)	1200	1500	2500	2500	4000	4000	>4000
LENGTH (FEET)	28.5	31.0	32.3	34.1		34.1	44.6
DIAMETER (INCHES)	54	54	54	74		74	83
WEIGHT (POUNDS)	28,800	32,500	35,700	64,000/73,000		73,000	~130,000

FBM Constraints and Growth

CHARACTERISTICS	598 CLASS (5 SUBMARINES)	608 CLASS (5 SUBMARINES)	616/627/640 CLASS SUBMARINES	726 CLASS (TRIDENT SUBMARINE)
LENGTH	382 FEET	410 FEET	425 FEET	560 FEET
BEAM	33 FEET	33 FEET	33 FEET	42 FEET
SURFACE DISPLACEMENT	6000 TONS	6900 TONS	7310 TONS 616 CLASS 7320 TONS 627 CLASS 7350 TONS 640 CLASS	16,600 TONS
SUBMERGED DISPLACEMENT	6700 TONS	7900 TONS	8260 TONS 616 CLASS 8240 TONS 627 CLASS 8250 TONS 640 CLASS	18,700 TONS
PROPULSION	STEAM TURBINE POWERED BY WATER-COOLED NUCLEAR REACTORS	SAME	SAME	SAME
TORPEDOES	6 BOW TORPEDO	4 BOW TORPEDO	4 BOW TORPEDO	4 BOW TORPEDO
ACCOMODATIONS OFFICE ENLISTED	12 BERTHS 127 BERTHS	15 BERTHS 130 BERTHS	14 BERTHS 130 BERTHS 616 CLASS 126 BERTHS 640 CLASS	16 BERTHS 139 BERTHS
MISSILES	16 POLARIS (A3) MISSILES	16 POLARIS (A3) MISSILES	16 POSEIDON (C3) OR 16 TRIDENT (C4) MISSILES	24 TRIDENT I (C4) OR TRIDENT II (D5) MISSILES
LAUNCH TUBES	16 TUBES LOCATED MIDSHIP	SAME	SAME	24 TUBES LOCATED MIDSHIP
LAUNCH CONTROL	GAS STEAM GENERATOR	AIR EJECTION	GAS STEAM GENERATOR	GAS STEAM GENERATOR
FIRE CONTROL SYSTEM	Mk 80	Mk 80	Mk 88	Mk 98
NAVIGATION SYSTEM	3 Mk 2 Mod 4 SINS (SHIPS INERTIAL NAVIGATION SYSTEM) AND NAVY NAVIGATIONAL SATELLITE RECEIVER	2 Mk 2 Mod 3 SINS AND SATELLITE RECEIVER	2 Mk 2 Mod 6 SINS, ESGM (ELECTROSTATICALLY SUPPORTED GYRO MONITOR), AND SATELLITE RECEIVER	2 Mk 2 Mod 7 SINS, ESGM OR ELECTROSTATICALLY SUPPORTED GYRO NAVIGATOR, AND SATELLITE RECEIVER
AIR CONDITIONING	OVER 300-TON CAPACITY	SAME	SAME	SAME

Fleet Ballistic Missile Weapon System Submarine Characteristics

MISSILES	SSBN	AUTHORIZED FUNDED (F)	IOC
A1	598/599/600	JAN 1958 - CUT USS SCORPION IN HALF - SSBN 598 ON "BORROWED" MONEY. FUNDED FEB 1958	15 NOV 1960
A1	601/602	29 JULY 1958	
A2	608 CLASS	23 DEC 1958	26 JUNE 1962
A2	616 CLASS	15 JULY 1960	28 OCT 1963 (618)
A3	626 CLASS	29 JAN 1961	23 SEPT 1964
C4	726 CLASS	FY 1974	1 OCT 1982
D5	734 CLASS	FY 1981	DEC 1989

SSBN/Missile Funding

(C3) POSEIDON SSBNs

HULL	NAME	CLASS
616	USS LAFAYETTE	
617	USS ALEXANDER HAMILTON	616
619*	USS ANDREW JACKSON	616
620*	USS JOHN ADAMS	616
622**	USS JAMES MONROE	616
623*	USS NATHAN HALE	616
624	USS WOODROW WILSON	616
625**	USS HENRY CLAY	616
626**	USS DANIEL WEBSTER	616
628	USS TECHUMSEH	627
631	USS ULYSSES S. GRANT	627
635*	USS SAM RAYBURN	627
636*	USS NATHANIEL GREENE	627
642	USS KAMEHAMEHA	640
644	USS LEWIS AND CLARK	640
645	USS JAMES K POLK	640
654	USS GEORGE C. MARSHALL	640
656	USS GEORGE WASHINGTON CARVER	640
659	USS WILL ROGERS	640

(C4) TRIDENT BACKFIT SSBNs

HULL	NAME	CLASS
627	USS JAMES MADISON	627
629	USS DANIEL BOONE	627
630	USS JOHN C. CALHOUN	627
632	USS VON STEUBEN	627
633	USS CASIMIR PULASKI	627
634	USS STONEWALL JACKSON	627
640	USS BENJAMIN FRANKLIN	640
641	USS SIMON BOLIVAR	640
643	USS GEORGE BANCROFT	640
655	USS HENRY L. STIMSON	640
657	USS FRANCIS SCOTT KEY	640
658	USS MARIANO G. VALLEJO	640

FBM TENDERS

NAME	HULL NO.	CLASS	CAPABILITY
USS HUNLEY	AS-31	31	C3
USS HOLLAND	AS-32	31	C3
USS SIMON LAKE	AS-33	33	C3/C4
USS CANOPUS	AS-34	33	C3/C4

(C4) TRIDENT I SSBNs

	SSBN	FY AUTH	NAME
1.	726	FY 74	USS OHIO
2.	727	FY 75	USS MICHIGAN
3.	728	FY 75	USS FLORIDA
4.	729	FY 76	USS GEORGIA
5.	730	FY 77	USS HENRY JACKSON
6.	731	FY 78	USS ALABAMA
7.	732	FY 78	USS ALASKA
8.	733	FY 80	USS NEVADA

(D5) TRIDENT II SSBNs

	SSBN	FY AUTH	NAME
9.	734	FY 81	USS TENESSEE
10.	735	FY 83	USS PENNSYLVANIA
11.	736	FY 84	USS WEST VIRGINIA
12.	737	FY 85	USS KENTUCKY
13	738	FY 86	USS MARYLAND
14.	739	FY 87	USS NEBRASKA
15.	740	FY 88	
16.	741	FY 89	
17.	742	FY 90	
18.	743	FY 91	
19.	744	FY 92	
20.	745	FY 93	

RETIRED POLARIS SSBNs
SEPT '79 - JAN '82

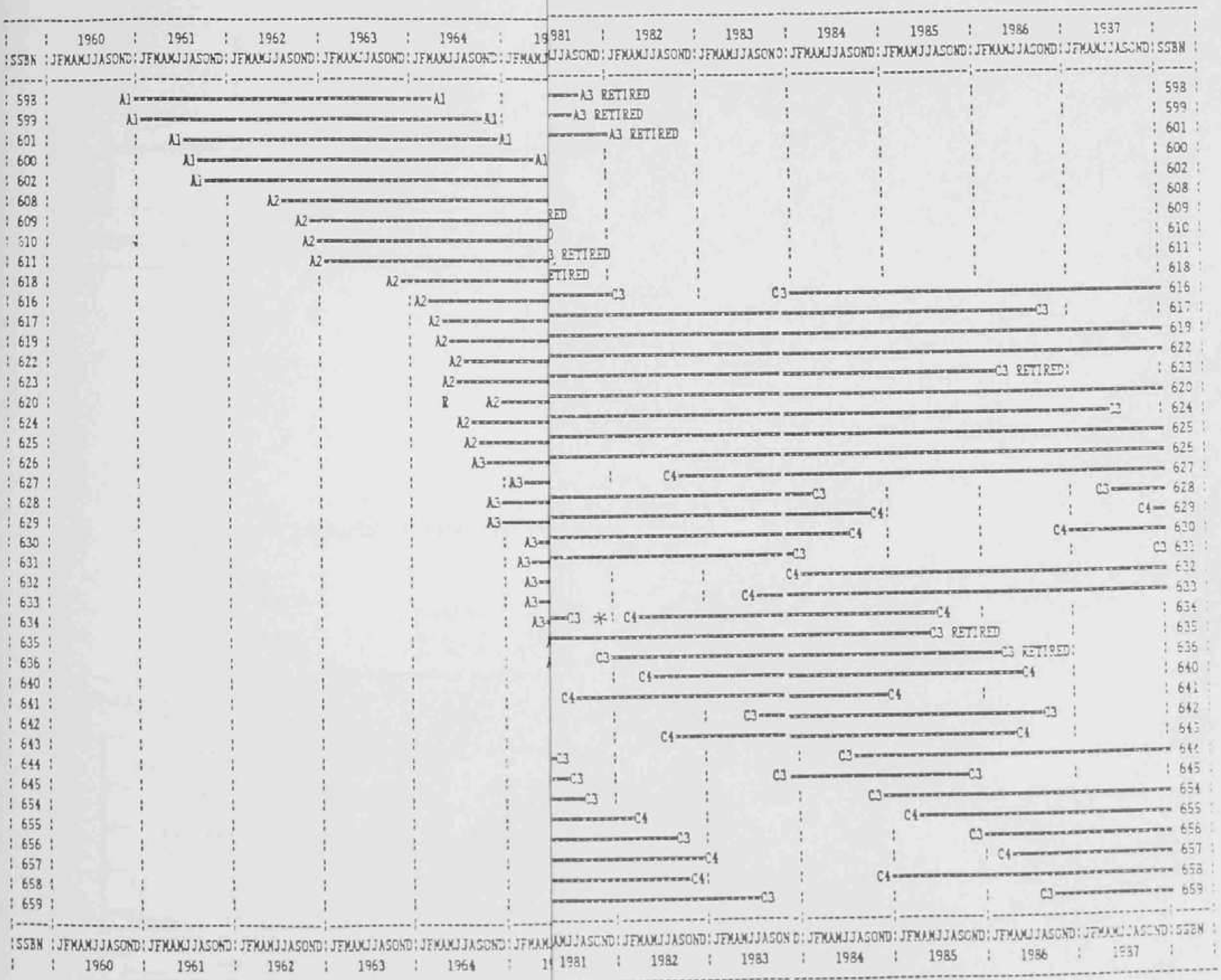
HULL	NAME
598	USS GEORGE WASHINGTON
599	USS PATRICK HENRY
600	USS THEODORE ROOSEVELT
601	USS ROBERT E. LEE
602	USS ABRAHAM LINCOLN
608	USS ETHAN ALLEN
609	USS SAM HOUSTON
610	USS THOMAS A. EDISON
611	USS JOHN MARSHALL
618	USS THOMAS JEFFERSON

T-AK SHIP NAMES AND NUMERS

NAME	HULL NO.
USNS NORWALK	T-AK 279
USNS VICTORIA	T-AK 281
USNS MARSHFIELD	T-AK 282
USNS VEGA	T-AK 286

* RETIRED/DISASEMBLED (ARM CONTROL)   ** POTENTIAL RETIREMENT FY 89/90

SSBNs – Support Ships

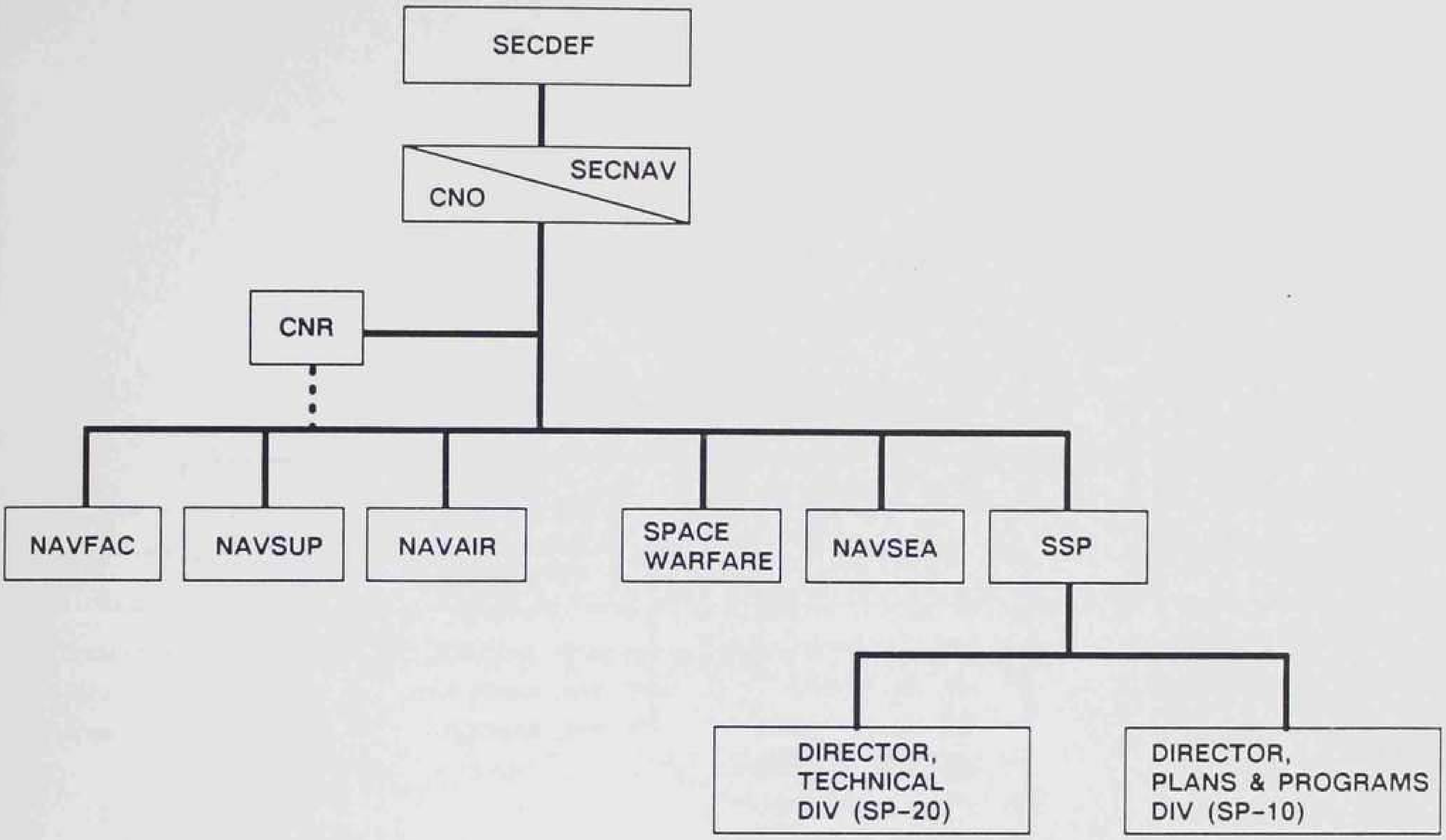


LEGEND

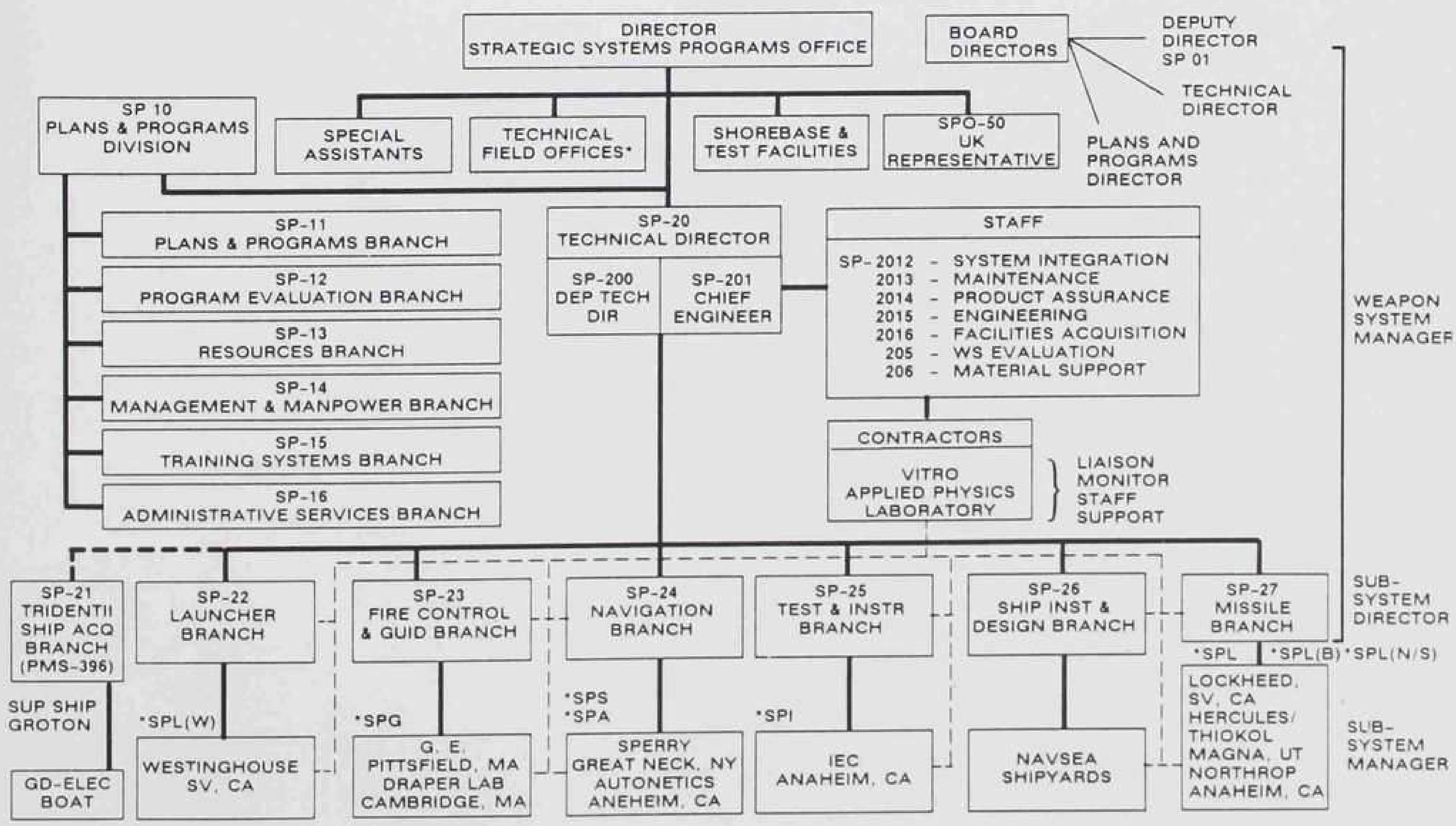
A1—A1 = Deployment Period

D OVERHAULS

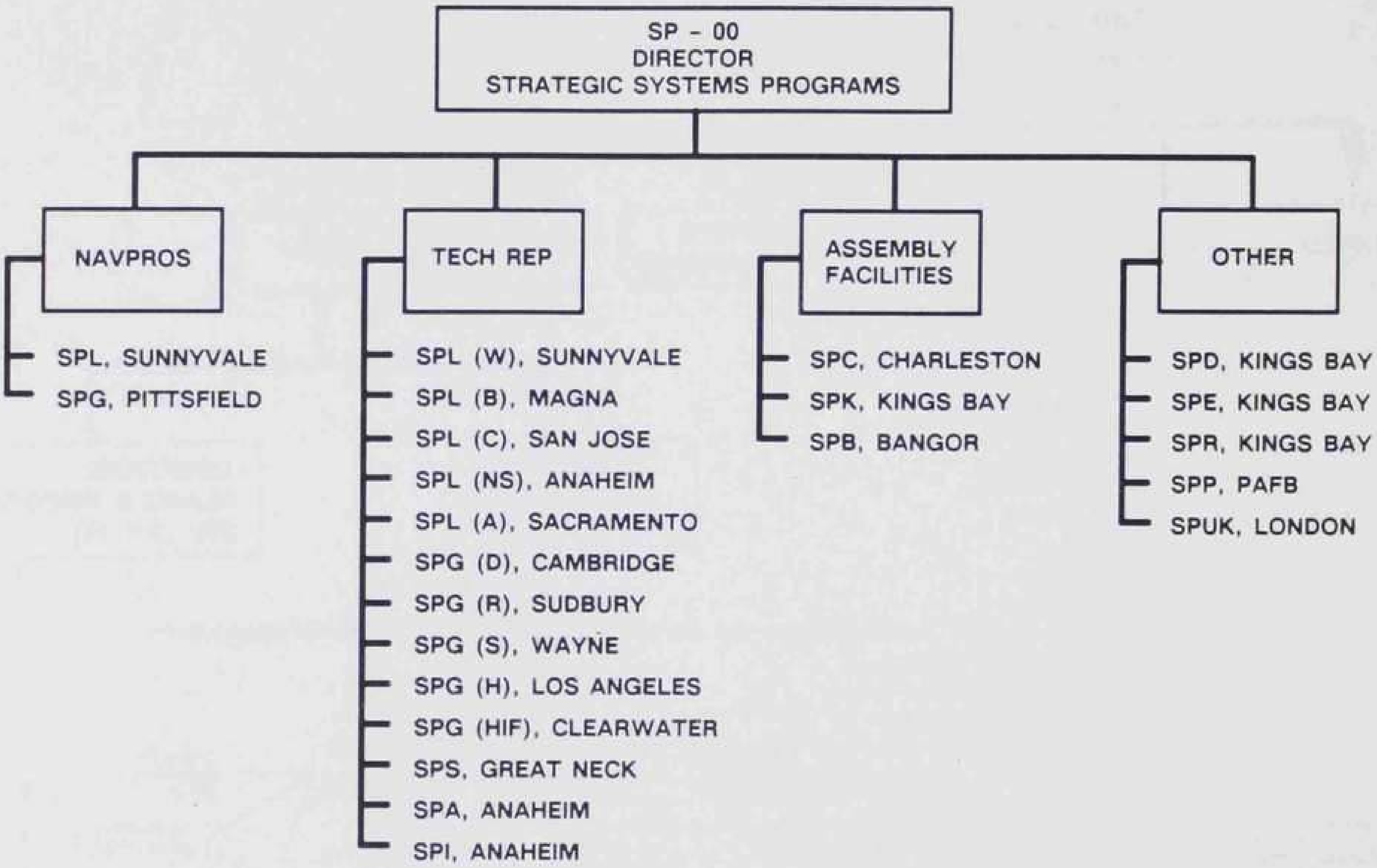
History of Weapon System Configuration



Organizational Relationships for Strategic Systems Programs Management



SSP Organization



SSP Field Activities

Program Management

- INTEGRITY AND FLEXIBILITY
- KNOW WHAT IS WANTED/NEEDED –
  THE PROGRAM COMES FIRST
- EXPECT THE UNEXPECTED
- NO FREE LUNCH – ANYPLACE
- MANAGEMENT TEAM CONTINUITY
- CRADLE TO GRAVE RESPONSIBILITY
- FREE ACCESS BY CUSTOMER

Basic FBM Strategy

- WHEN YOU HAVE WHAT YOU WANT – DO NOT CHANGE IT
  (GET THERE DURING DEVELOPMENT)
- OPEN ENDED LIFE
- DESTRUCTIVE TESTING NECESSARY
- DO NOT REACT TO LIMITED SAMPLE DATA
- WHEN YOU MUST CHANGE – UNDERSTAND THE CHANGE BEFORE INTRODUCING IT AND CHANGE TOTAL POPULATION
- PROCESS CHANGES – INCLUDING BREAKS IN PRODUCTION MUST BE TREATED AS A CHANGE

Establish Definition/Contracting – Mutual Effort

ESTABLISH

- RELATIVE PRIORITIES OF PROGRAM CHARACTERISTICS
- PROGRAM PECULIAR STRATEGIES

DEFINE

- MINIMUM ACCEPTABLE
- EXPECTED OUTCOME
- MAXIMUM DESIRED

CONTRACT

- MINIMUM NUMBER OF REQUREMENTS
- CLEAR STATEMENT OF PRIORITIES (INCENTIVES)
- PLACE RESPONSIBILITY AND AUTHORITY ON THE CONTRACTOR

DEPARTMENT OF THE NAVY
SPECIAL PROJECTS OFFICE
WASHINGTON 25, D. C.

IN REPLY REFER TO:

SP 20-LS:dbc
9784/1-1
5 Dec 1961

From: Director, Special Projects

To: Distribution

Subj: POLARIS Missile Design and Process Change Control Policy

Ref: (a) SP ltr SP-20-LS:pp, X11-2/1 of 15 Dec 1959
(b) SP ltr SP-2017-CEE:dbc of 1 July 1959

1. Reference (a) is hereby cancelled and superseded by this letter.

2. It is the purpose of this letter to indicate the degree of tactical design and process control desired on POLARIS missiles with a view to attaining high reliability, operability and maintainability. It is the desire of the Special Projects Office that all tactical missiles be essentially identical within any missile type (i.e., A1P, A2P, A3P, etc.). This desire can be realized by freezing and documenting design and manufacturing processes at the time that it has been reasonably determined that a reliable, operable and maintainable missile can be manufactured to that design using those manufacturing processes.

3. Considering the above objectives and the short production run of the tactical POLARIS Missiles of a given type, only three types of changes to authenticated design disclosure process and test documents (drawings, OSs, and ODs) will be seriously considered. These three types of changes and the conditions under which they be considered are:

a. Mandatory changes are those changes of design or process which have been fully substantiated as complete corrections of major failures to meet the performance or reliability objectives of the Technical Development Plan, or substantiated as significant reductions in demonstrated hazards to personnel, submarine, tender or depot. Conclusive flight or static test information and design evaluation tests or qualification production acceptance tests confirmed by flight tests will be accepted as substantiation of correction of a major failure to meet objectives. Not included as mandatory are changes of design or process for the purpose of improved producibility or improved maintainability (except changes of processes to meet drawing and specification requirements needed for spare part interchangeability) of improved service life or of improved economy or ease of manufacture.

POLARIS Missile Design and Process Change Control Policy (Sheet 1 of 4)

b. Clarification changes are those correcting drawing and specification errors or clarifying requirements without changing the basic requirement, design, or process. These changes will be accepted when it can be positively shown that the majority of missiles and/or missile components produced up to that time (including successful flight test vehicles) were in fact, made in conformance with the proposed change and not to the claimed erroneous drawings, OS or OD. When evidence supporting or denying a presumption that missiles successfully flight tested were in fact manufactured in accordance with the proposed clarification change cannot be produced, demonstration that mating parts will not fit if made in accordance with current drawing specification requirements and still be manufactured in such a way that the missile could not perform to meet the performance or reliability objectives of the Technical Development Plan, will be accepted in support of a proposed clarification change. If either is not the case, the proposed change does not qualify as a clarification change.

c. Correction changes are those changes to authenticated drawings, OSs, and ODs which are required to prevent an inadvertent change in part or process during the transition from the development/flight test portion of the program to the tactical production program. When in the early phases of the tactical production program using the authenticated documents, it is discovered that the product produced is different than, produced by a different process than, or tested by a different method or to different limits than those used during the R&D and flight test phase of the program, then changes to the authenticated documents shall be accepted to make the tactical production part the same as that produced during the successful R&D flight test program.

4. Changes to processes, tests and inspection procedures, and acceptance limits are to be considered as design changes the same as changes to basic drawings and specifications.

5. The incorporation of a mandatory change requires reidentification up to and including the top missile drawing and specification. The incorporation of a clarification change or correction change will not require reidentification above the level of the unit of inspection directly affected.

6. Requests for approval of proposed changes to authenticated drawings, OSs and ODs which are deemed by the addressee to meet the above criterion for mandatory changes will be submitted to the Special Projects Office via the appropriate Special Projects Field Office. Each such request must be accompanied by the following:

a. Description of change.

b. Summary of evidence with reference to source of detailed data supporting the existence of the situation described in paragraph 3 and evidence substantiating the proposed change in accordance with paragraph 3.

POLARIS Missile Design and Process Change Control Policy (Sheet 2 of 4)

SP 20-LS:dbc
9784/1-1
5 Dec 1961

Subj: POLARIS Missile Design and Process Change Control Policy

c. Urgency of change and proposed effective date.

d. Documents affected (drawings, OSs, ODs, OCDs, etc.).

e. Missile on which change would take effect and inspection lot of material involved.

f. Requirement or need for making change in material or missiles previously produced. (In the event that the proposed change is a mandatory change with an effectivity other than A1P-1 and up, A2P-1 and up, A3P-1 and up, etc., the proposed change shall be accompanied by a SPALT proposal for the correction of the design defect for those articles manufactured prior to the incorporation of the change. If it is not deemed necessary to incorporate the change into material and missiles previously produced than that change by definition may not qualify as a mandatory change.)

g. Estimated change in costs for all currently scheduled missiles of a given type (i.e., A1P, A2P, A3P, etc.).

7. By copy of this letter the Bureau of Naval Weapons Representative, Sunnyvale and the Bureau of Naval Weapons Technical Liaison Officer, Pittsfield, are hereby authorized to approve clarification changes pursuant to such procedures as they consider appropriate when all conditions of paragraph 3.b., have been met. Provided, however, that rework of parts already manufactured at the time of approval of a clarification change will be required only when it is demonstrated that the part will not fit, or when evidence is at that time available that the probability of the parts already made are functioning as intended is not greater than 0.70. A copy of all clarification change approval actions will be submitted to the Special Projects Office.

8. By copy of this letter the Bureau of Naval Weapons Representative, Sunnyvale, and the Bureau of Naval Weapons Technical Liaison Officer, Pittsfield, are hereby authorized to approve correction changes pursuant to such procedures as they consider appropriate when all conditions of paragraph 3.c., have been met; provided, however, that effectivity of the correction change will be A1P-1 and up, A2P-1 and up, or A3P-1 and up; that no SPALT is required to achieve this required effectivity; and that rework of parts already manufactured at the time of approval of the correction change will not be required only when it is demonstrated that the parts manufactured will fit and when evidence is at that time available that the property of the parts already made, functioning as intended, is greater than 0.70. A copy of all correction changes disapproval actions will be submitted to the Special Projects Office.

POLARIS Missile Design and Process Change Control Policy (Sheet 3 of 4)

SP 20-LS:dbc
9784/1-1
5 Dec 1961

Subj: POLARIS Missile Design and Process Change Control Policy

9. In order that an appropriate definition be maintained for deviations and changes, approvals of deviations pursuant to the delegations of authority contained in reference (b) will be limited to three months duration. Requests for renewal of deviations will be submitted to the Special Projects Office.

/s/ Levering Smith
LEVERING SMITH
Technical Director

POLARIS Missile Design and Process Change Control Policy (Sheet 4 of 4)

STRATEGIC SYSTEM PROGRAMS FBM LEADERSHIP TENURE	FBM EXPERIENCE (YEARS)
VADM W. F. RABORN JR., USN, RET. DIRECTOR, 1955-62 (6.5 YEARS)	6.5
VADM I. J. GALANTIN, USN, RET. DIRECTOR, 1962-65 (3.0 YEARS)	3.0
VADM L. SMITH, USN, RET. DIRECTOR, 1965-77 (13.0 YEARS) TECHNICAL DIRECTOR (8.0 YEARS)	21.0
RADM R. H. WERTHEIM, USN, RET DIRECTOR, 1977-80 (3.0 YEARS) TECHNICAL DIRECTOR, MISSILE BRANCH HEAD, REENTRY SYSTEMS (17.0 YEARS)	20.0
VADM G. R. CLARK, USN, RET. DIRECTOR, 1980-85 (5.0 YEARS) TECHNICAL DIRECTOR, LAUNCHER BRANCH HEAD, GUIDANCE BRANCH HEAD, MISSILE ENGINEERING (12.5 YEARS)	17.5
RADM K. C. MALLEY, USN DIRECTOR, 1985-PRESENT (3.0 YEARS) TECHNICAL DIRECTOR MISSILE BRANCH HEAD, NAVAL PLANT, REPRESENTATIVE (16.0 YEARS)	19.0
COMBINED TOTAL	87.0

AS OF 1988

FBM Leadership Tenure