TRIDENT II MISSILE

TEST PROGRAM

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PREFACE

This year the Congress will consider procurement of the first operational Trident II submarine-launched ballistic missiles, many of which will be dedicated to the Trident II missile test program. This test program is, as currently planned, the largest in the history of U.S. strategic ballistic missiles. It is also expensive, costing about 14 billion dollars between fiscal years 1987 and 1999. Would a smaller and less expensive test program adequately support the Trident II program? This is an important question as the Congress considers the new defense budget. As requested by the Defense Subcommittee of the Senate Committee on Appropriations and by the Senate Committee on Armed Services, this analysis by the Congressional Budget Office (CBO) examines the statistical and operational objectives of the Trident II test program and compares the current program with two alternative programs. In accordance with CBO's mandate to provide objective analysis, the paper makes no recommendations.

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Rudolph G. Penner
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February 1986

SUMMARY

The Trident II submarine-launched ballistic missile (SLBM) is being developed to replace the Trident I SLBM on the Navy's Trident submarines. The Trident II will have greater accuracy and payload than the Trident I, giving it significantly improved capability against hardened targets. The Navy envisions that the Trident II missile, the first deployment of which is planned for December 1989, will eventually be deployed on about 20 Trident submarines.

The Navy plans to support deployment of the Trident II with a three-part flight test program that would be the largest and most expensive ballistic missile test program in the history of US armaments. The Operational Test (OT) program, currently planned for 40 flights during the first three years that the Trident II is deployed, is designed to establish reliability and accuracy parameters for use in the Single Integrated Operational Plan (SIOP), the nation's blueprint for conducting nuclear attacks. The Follow-on Test (FOT) program, currently planned for 260 flight tests over twenty years (16 flights per year for the first five years and 12 per year thereafter), is designed to update SIOP parameters, to detect developing problems, and to test potential remedies. Finally, a 56-missile test program that would be conducted during submarine Demonstration and Shakedown Operations (DASO) is designed both to help detect and remedy engineering problems and to demonstrate that a newly completed or overhauled submarine is fully capable.

This paper finds that the test program proposed by the Administration exceeds the minimum necessary to meet guidance established by the Joint Chiefs of Staff (JCS) and to provide a solid statistical foundation for calculating SIOP parameters. However, decreasing the current test program would increase the length of time required to detect emerging problems and would diminish the exploration of missile performance under diverse flight profiles and launch environments.

Restricting the test program to the minimum necessary to meet JCS guidance would reduce the test program by 175 missiles, saving approximately $1.3 billion during the next five years and $6.7 billion over the length of the program. If the Congress were to allow more missiles, reducing the current program by 105 missiles rather than 175, lesser savings would be achieved. This would provide some flexibility in the test program

and would save about $1 billion during the next five years and $4.1 billion over the length of the program (see Summary Table).

RESULTS OF ALTERNATIVE TEST PROGRAMS

CBO analyzed two alternative test programs in detail, each of which would assure compliance with JCS guidance. The programs provide varied levels of tests for documenting missile performance under diverse conditions, detecting emerging problems, and updating the accuracy and reliability parameters employed in the SIOP.

Moderate Test Program

This alternative would limit the number of OT missiles to 36, preserving a 71 percent probability of meeting JCS requirements for sample reliability as an estimator of true reliability rather than 90 percent under the Administration's program. It would also restrict the FOT program to 10 missiles per year for the first five years and to 8 missiles per year thereafter. This reduced FOT program would continue to provide estimates of high quality for the reliability and accuracy parameters employed in the SIOP, as well as some flexibility for studying Trident II performance over diverse flight paths and environments. On the other hand, a reduced FOT program would increase by up to 5 months (from 10 months to 15 months) the average time required for one important FOT function--detecting emerging problems. Finally, this alternative would restructure the DASO program on the basis of the demand for highly structured test flights, rather than on the schedule of submarine construction and overhaul, holding the size of the program to 45 missiles. Although the primary purpose of this revised DASO program would be to augment the detection and correction of emerging problems, the Navy could, if it desired, schedule the flights to demonstrate the capability of each new Trident submarine, each Trident submarine refitted with Trident II missiles, and most Trident submarines that have undergone a major overhaul.

Minimum Test Program

This alternative would provide the same OT program as the previous alternative but reduce the FOT program to the minimum required by JCS guidance: six missile flights per year. It would still obtain good estimates of missile reliability and accuracy (the expected error in the estimate of accuracy, as measured by the Circular Error Probable (CEP), would be about 26 feet as compared to 20 feet under the Administration program) but would

SUMMARY TABLE. TRIDENT II PROCUREMENT COSTS a/
(By fiscal year)

Alternative	1987	1988	1989	1990	1991	Total 1987-1991	Total Program
Administration							
Quantity	27	66	66	66	72	297	844
Cost b/	1.9	2.5	2.6	2.6	2.5	12.1	32.8
Moderate Test							
Quantity	20	60	60	60	70	270	739
Cost b/	1.5	2.4	2.4	2.4	2.4	11.1	28.7
Savings c/	0.4	0.1	0.2	0.2	0.1	1.0	4.1
Minimum Test							
Quantity	20	60	60	60	60	260	669
Cost b/	1.5	2.4	2.4	2.4	2.1	10.8	26.1
Savings c/	0.4	0.1	0.2	0.2	0.4	1.3	6.7

a. All costs and savings are in billions of current year dollars.

b. The cost includes the procurement costs of all Trident II missiles (missiles that will be deployed as well as missiles that will be tested) and the costs of conducting flight tests.

c. Savings as compared to the Administration alternative.

provide less capability to study Trident II performance over diverse flight paths and environments. Also, the reduced FOT program would increase the average time required to find an emerging problem by up to 10 months. Finally, this option would reduce the size of the DASO program to 25 missiles, providing two highly structured flights per year for five years and one flight per year for fifteen years to augment ongoing research on the missile. Although based on the demand for highly structured flights rather than on the schedule for submarine construction and overhaul, this DASO option would enable the Navy to conduct at least one missile flight for each new Trident submarine and each submarine refitted with Trident II missiles.

CHAPTER I. INTRODUCTION

The Trident II missile is intended to replace the Trident I missile in the Navy's Trident submarines. The Department of Defense has requested this missile because it has greater accuracy and power than the Trident I. The Trident II can carry more warheads of a given size to a specified range than the Trident I or it can carry a comparable number of warheads to a greater range, giving the Trident submarine more area to patrol within striking distance of the Soviet Union. A third option is to carry a comparable number of warheads of greater size. This capability, in combination with improved accuracy, would increase significantly the probability of destroying hardened targets.

Although the Trident II is much more powerful than the Trident I, in many ways the two missiles are similar. Both missiles have three stages of solid propellant, inertial guidance with stellar update, and gas hydraulics to control the thrust vector. Also, both missiles will, when fully loaded, have essentially the same range. The Trident II, however, will employ graphite rather than kevlar casings on stages one and two, will have improved all-attitude guidance, and will be able to carry either the Mark IV warhead (now deployed on the Trident I) or the larger Mark V warhead under development.

Despite the similarity of the Trident II to the Trident I, the development of the Trident II will take a full six years. The missile entered Full Scale Engineering Development in October 1983, and the first test flight is scheduled for January 1987. Barring unforeseen difficulties, initial deployment will occur in December 1989. To meet the testing and deployment demands the Navy is requesting 27 missiles in fiscal 1987, and 66 to 72 missiles per year subsequently. The Navy envisions that eventually 24 Trident II missiles will be deployed on each of 20 Trident submarines.

The Navy plans an extensive Trident II flight test program to establish and update the performance parameters for the missile (accuracy and reliability) and to maintain it, solving engineering problems as they develop. The flight test program, in which missiles are fired from submarines simulating the conditions of an ordinary patrol, has three parts. 1/ A three-

1. Neither the Research and Development flight test program, which has already been funded under Research and Development accounts, nor the Fleet Return Evaluation Program, which does not involve flight tests and does not increase the number of missiles that must be procured, is addressed in this paper.

year Operational Test (OT) program of 40 missiles is designed to establish reliability and accuracy parameters for use in the strategic Single Integrated Operational Plan (SIOP). The SIOP provides detailed timing and targeting blueprints for the employment of U.S. strategic nuclear weapons. A 20-year Follow-on Test (FOT) program of 260 missiles is designed to provide data to update the reliability and accuracy parameters in the SIOP. Finally, 56 flight tests would be conducted during Demonstration and Shakedown Operations (DASO) to help the Navy to detect and repair emerging problems in the missiles. The flight tests in all three programs would serve to enhance deterrence by demonstrating to the Soviets the capabilities of U. S. strategic forces.

The total test program requiring 356 missiles is large in comparison to the planned 123-missile test program for the MX, or the Trident I test program of 208 missiles (see Table I). It is also expensive. Since each Trident II missile costs about $40 million and the conduct of each flight test about $5 million, a reduction in the test program could realize significant budgetary savings. 2/ The remainder of this paper reviews the OT, FOT, and DASO programs in detail and assesses the costs and benefits of current and alternative plans.

2. Unless otherwise specified, in this paper all costs are expressed in current year dollars and all dates refer to fiscal years. The cost per missile and cost per flight are based on the total program procurement costs (Research and Development costs are excluded) divided by the number of missiles and the total costs for conducting missile tests divided by the number of flight tests.

TABLE 1. COMPARISON OF TEST PROGRAMS FOR STRATEGIC BALLISTIC MISSILES

	Operational Test Missiles a/				Other Test Missiles	
	OT/FOT	DASO	A&S b/	TOTAL	R&D	FREP c/
ICBMs:						
Minuteman I	210	N.A.	24	234	56	N.A.
Minuteman II	171	N.A.	14	185	20	N.A.
Minuteman III	242	N.A.	17	259	25	N.A.
MX	108	N.A.	15	123	20	N.A.
SLBMs:						
Polaris (A-1)	23	36	N.A.	59	42	16
Polaris (A-2)	112	59	N.A.	171	28	39
Polaris (A-3)	141	83	N.A.	224	55	22
Poseidon (C-3)	228	69	N.A.	297	25	22
Trident I (C-4)	176	32	N.A.	208	25	30
Trident II (D-5)	300	56	N.A.	356	30	30

SOURCE: The Air Force provided the data on ICBM programs. The Navy provided the data on SLBM programs.
NOTE: N.A. = not applicable.

a. This category comprises operational missiles that are destructively tested (either in flight tests or on the ground) for the purpose of updating SIOP parameters or detecting and resolving engineering problems.

b. The Air Force Aging and Surveillance program is designed to help detect missile characteristics caused by aging--such as the corrosion of electrical connections--before they would cause a serious problem in the performance of deployed missiles. A deployed missile is removed from its silo and dismantled. Components are inspected and tested; motors are fired on the ground.

c. The Fleet Return Evaluation Program provides a reserve so that enough missiles will be available for scheduled deployments even though some missiles are being transported, dismantled, inspected, or reassembled. Missiles are likely to be in one of those conditions as a result of two procedures. First, the Navy regularly removes a deployed missile from a submarine to examine it for signs of deterioration. These missiles--called Service Life Evaluation (SLE) missiles--are not destroyed. Following ground-based inspections and tests, the components reenter the parts inventory and are incorporated into new or refurbished missiles as required. Second, when a submarine undergoes a major overhaul, all the missiles on that submarine are dismantled. As with SLE missiles, the components reenter the parts inventory following inspection and, if needed, repair.

CHAPTER II. THE TRIDENT II TEST PROGRAM

The test program for Trident II missiles has two fundamental objectives. The first objective is to establish and update estimates for the reliability and accuracy of the missile and its warheads. The Joint Strategic Target Planning Staff (JSTPS) employs these estimates along with other weapon characteristics--the footprint of the missile, time to arrival, and yield--to develop an optimal Single Integrated Operational Plan (SIOP) for the use of the weapon under a variety of scenarios and strategies.

The second objective is to detect problems and test remedies to maintain the performance of the missile. This is accomplished through the flight tests, inspections, and ground-based tests of components. The problems might include either inferior parts such as improperly cast motors or flaws that develop with age and exposure such as cracked insulation or corroded electrical connections.

To accomplish these basic objectives the Navy has divided the test program into the three parts mentioned above--Operational Test (OT) program, Follow-on Test (FOT) program, and Demonstration and Shakedown Operations (DASO). The first two parts are guided by minimum requirements established by the Joint Chiefs of Staff (JCS). A service must design the OT program so that there is a specified confidence in the sample reliability as an estimator of true reliability. Similarly, a service must design the FOT program so that there is at least a specified confidence in detecting a change in reliability.

JCS guidance allows the services considerable flexibility. The guidelines apply to no other parameter than reliability, establish no test ceilings or minimally acceptable level of reliability, and do not address the speed with which emerging engineering problems must be detected and remedied. A service is free, therefore, to set additional standards for the test program of a particular system on the basis of the system's role and the cost of additional flight testing.

With JCS standards in mind, it is possible to examine in greater detail the three parts of the Navy test program for the Trident II missile.

The Operational Test Program

The OT program has two goals. The primary goal is to provide good estimates of performance parameters for use in the SIOP. The second goal is to document the missile's performance under diverse conditions--such as different flight profiles and environments--thereby improving the Navy's ability to employ the missile effectively under such conditions.

The two important SIOP performance parameters provided by the OT program are reliability and accuracy. Reliability is the probability that a missile will deliver a reentry vehicle (RV) within a specified distance of its target. Accuracy, which is commonly calculated by the Circular Error Probable (CEP), is a measure of the distance between the target and the arriving RVs. 3/ As the size of the test program is increased, the error in the estimates of these two parameters will, on average, decrease.

JCS guidance for the OT program is based on this inverse relationship between program size and statistical error. Specifically, JCS guidance requires an OT program to assure a 90 percent probability that the true reliability is no more than 10 percent less than the reliability of the sample. 4/ For example, JCS guidance is satisfied if 40 missiles are tested and 36 are successful since there is a 92 percent probability that the true reliability is greater than 80 percent--the sample reliability minus 10 percent.

The application of JCS guidance is complicated, however, because the sample reliability, which influences the probability that the true reliability will be within 10 percent of the sample reliability, cannot be known in advance. Given this handicap, a useful statistical approach is to establish the probability of meeting JCS guidance on the basis of the anticipated true reliability. Thus, if the true reliability is 90 percent, the Navy's planned OT program of 40 missiles will have a 90 percent probability of meeting JCS guidance (see Figure I-A). 5/ If the program was cut to 36 missiles, the probability of meeting JCS guidance would drop to 71 percent.

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3. Specifically, CEP is the radius of a circle centered on a target such that a warhead aimed at that target has a 50 percent probability of landing within the circle.

4. *Department of Defense Appropriations for 1986: Part 7*, Hearings before a Subcommittee of the Committee on Appropriations, the House of Representatives, 99:1 (1985), p. 317.

5. The reliability of SLBMs is commonly projected to be between 80 and 90 percent. Although it is not possible to determine currently where Trident II reliability will fall

PROBABILITY OF MEETING JCS GUIDANCE

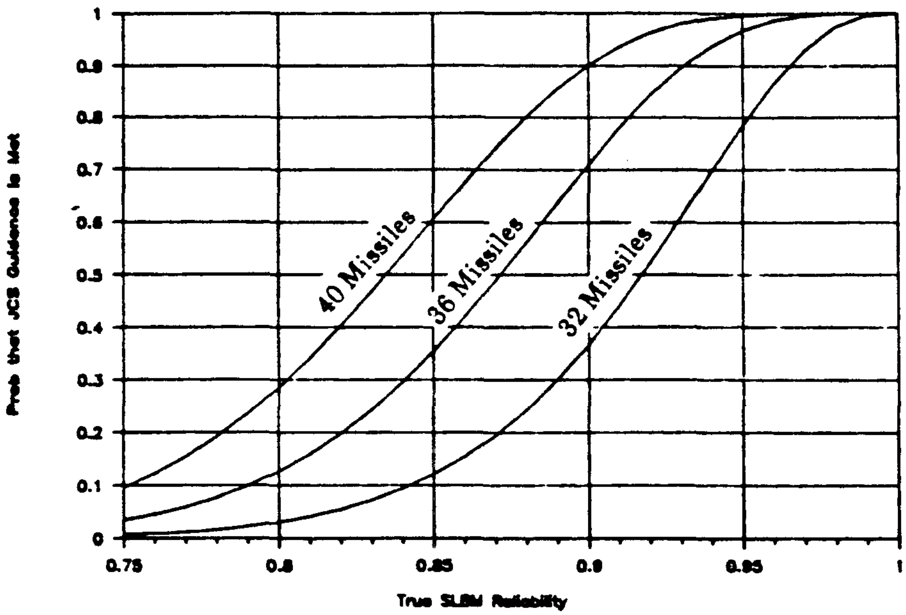

FIGURE I-A

EXPECTED ERROR IN RELIABILITY ESTIMATE

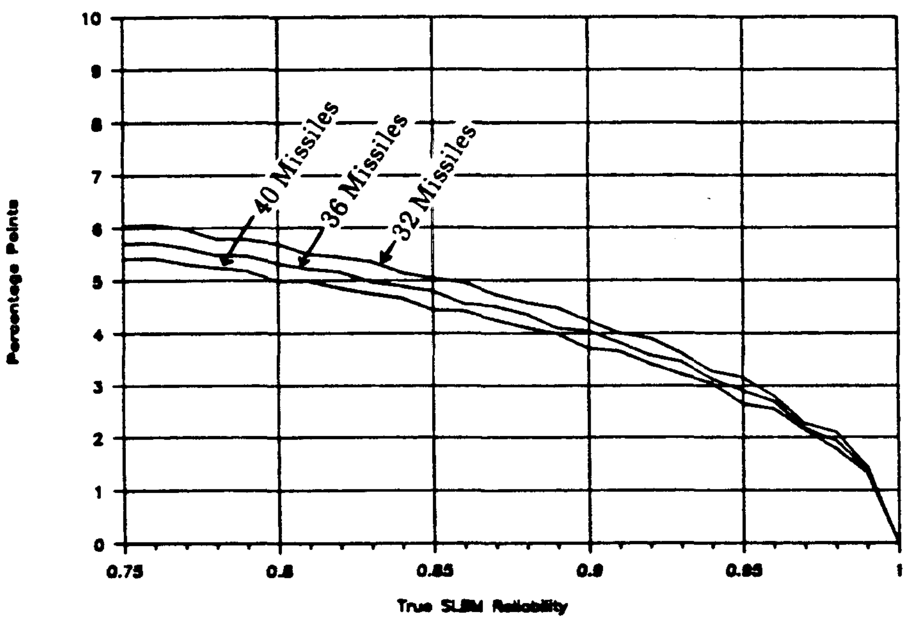

FIGURE I-B

NOTE: Figure I-A displays the probability of meeting JCS guidance for three alternative OT programs. JCS guidance for an OT program requires a 90 percent probability that the true reliability is no more than 10 percent less than the sample reliability.

Figure I-B displays the expected error in the reliability estimate for the same alternatives. The expected error is the average absolute value of the difference between the true reliability and the sample reliability. For example, if the expected error is four percentage points, on average the reliability estimate employed in the SIOP will be four points less or more than the true reliability.

The foregoing methodology indicates the probability of meeting JCS guidance but does not provide a direct measure of the quality of the reliability estimate as a consequence of program size. An alternative approach, expected error, provides a more direct measure. The Navy's program of 40 test missiles means that the estimated reliability will, on average, be in error by 3.7 percentage points. 6/ (That is, the expected absolute value of the true reliability minus the sample reliability would be 3.7 percentage points.) The expected error would rise to 4.0 percentage points with a test program of 36 missiles (see Figure I-B).

In addition to generating good reliability and accuracy estimates, a goal of the OT program is to chart the performance of the Trident II under diverse conditions. Such observations improve the ability of the Navy to employ the missile effectively under such conditions and reveal problems or poor designs that might go unnoticed under more moderate conditions. For example, the ablative properties of a reentry vehicle (that is, the manner in which the tip of a reentry vehicle erodes to dissipate heat generated by atmospheric friction) might cause it to behave differently at one speed and reentry angle than at another speed and reentry angle. Because of the large number of conditions under which the Trident II must perform, the OT program as well as the R&D program plays an important role in charting missile performance.

Finally, it is worth noting that the final size of the OT program could be changed easily on the basis of test results. If the Trident II OT program were to have a very high success rate and thus were to satisfy JCS guidance before the planned 40 missiles had been launched, the Navy might decide to proceed earlier than planned into the FOT program. 7/ On the other hand, if the OT program encountered significant problems, the Navy could extend it by moving missiles from the FOT to the OT program and postponing the FOT program accordingly.

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within that range, a reliability of 90 percent is employed for making programmatical comparisions in thispaper. For reliability projections see Thomas J. Downey, "How to Avoid Monad and Disaster," *Foreign Policy* (Fall 1976); and Bernard T. Feld and Kosta Tsipis, "Land-Based Intercontinental Ballistic Missiles," *Scientific American* (November 1979).

6. As before, the programmatical comparisons are based on the assumption that true SLBM reliability is 90 percent. For comparisons that vary this assumption, see Figure I-B.

7. The Navy ended the successful OT program for the Trident I after 31 of the planned 40 OT test missiles had been launched.

The Follow-on Test Program

The size of the Follow-on Test program exceeds the minimum necessary to comply with JCS guidance for identifying a deterioration in missile reliability. The Navy currently plans a 20-year Follow-on Test (FOT) program of 16 missile flight tests per year for five years (1993-1997) and 12 tests per year thereafter. 8/ Meeting JCS guidance, which requires a specified confidence in identifying a deterioration in the reliability of the force, would require only six missile flights per year. 9/

The Navy has planned a much larger FOT program for three reasons. First, although JCS guidance pertains only to reliability, the Navy is interested as much in the accuracy of the Trident II force as in its reliability. Second, special operating requirements increase the demand for test data. And third, the annual level of the FOT program is a significant factor in determining the speed with which problems are detected and remedied. It is not clear, however, that any of those reasons fully justifies an FOT program larger than that required to meet JCS guidance.

Accuracy. The Navy notes that if the JCS guidelines for confidence in missile reliability were applied to missile accuracy as measured by the CEP, 14 tests per year--assuming a reliability of 0.9--would be required. This level of testing is generally consistent with the Navy plan for 16 tests per year for five years and 12 tests per year thereafter.

It is not obvious, however, that the extra FOT tests planned beyond the required six would substantially improve the quality of the estimate of accuracy that would be employed in the SIOP. As in the case of the reliability parameter discussed in the section on the OT program above, a

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8. The FOT program would end in the year 2012 although the Trident II, as currently planned, would be deployed for an additional 10-20 years. To end the FOT program in 2012 is not unreasonable, however, since it is not clear that it will be necessary to update SIOP parameters annually thereafter. If the need does arise, the Navy could prolong the FOT program by testing fewer missiles per year before 2012. Also, the first Trident II carrying submarines will probably be retired between 2015 and 2020, providing additional missiles that could be employed in tests.

9. This calculation is based on the interpretation of JCS guidance, the details of which are classified, by the Strategic Air Command and by the Advanced Physics Laboratory (APL) at Johns Hopkins University. Although the two institutions employ different methodologies, in this context the two methodologies produce the same answer.

useful measure of the quality of the parameter is the expected error. 10/ In a case where the true CEP of the force is steady at 500 feet, the expected error in the SIOP CEP parameter would be no more than six feet higher with six tests per year than with the currently planned program (see Figure II-A). 11/ In a case where the true CEP of the Trident II fluctuates between 525 feet and 475 feet, the difference in the expected error of the SIOP CEP parameter as a result of six tests per year again is less than six feet (see Figure II-B). 12/ Since a difference of six feet is insignificant in the context of nuclear weapons of more than 100 kilotons, testing six rather than 12-16 missiles per year would not affect the quality of the accuracy parameter employed in the SIOP. 13/ 14/

Special Operating Requirements. The Navy notes that the mission of launching missiles at sea presents special operating requirements that increase the demand for test data and, therefore, for FOT missile flights. For example, while the range flexibility demanded of a land-based intercontinental ballistic missile (ICBM) is fairly limited, the Navy must be able to employ a sea-launched ballistic missile (SLBM) effectively at a broad span of ranges. Consequently, the Navy conducts tests at significantly different ranges and reentry angles to chart the effect of range and reentry angles on accuracy, reliability, and time to arrival. Also, the Navy must be able to conduct a ripple launch--the sequential firing of a group of missiles

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10. The expected error is the expected absolute difference between the true CEP and the estimated CEP. The error associated with potential sample CEP measurements (the absolute value of CEP minus potential sample CEP) is weighted by the probability of getting those measurements. The weighted errors are then summed.

11. A CEP of 500 feet for the Trident II is used in this paper for the purpose of illustration. Public reports of the Trident II's CEP range from 400 to 600 feet. See "Counterforce at Sea: The Trident II Missile" in *Arms Control Today* (September 1985). Also see the *Nuclear Weapons Databook*, Volume 1.

12. This fluctuation can occur, for example, if problems develop and then are resolved.

13. A change of six feet in the CEP would induce a change of less than one percentage point in the probability that a Trident II warhead (Mark IV or Mark V) would destroy a 5000 psi target. See Lynn Davis and Warner Schilling, "All You Ever Wanted To Know About MIRV and ICBM Calculations But Were Not Cleared to Ask," in *The Journal of Conflict Resolution*, Vol. XVII, No. 2 (June 1973).

14. These calculations are based on the inclusion of all flight test data collected in the current and prior years. This is the procedure used by the Navy except when a change in a component invalidates previous data pertaining to that component.

EXPECTED ERROR IN SIOP CEP

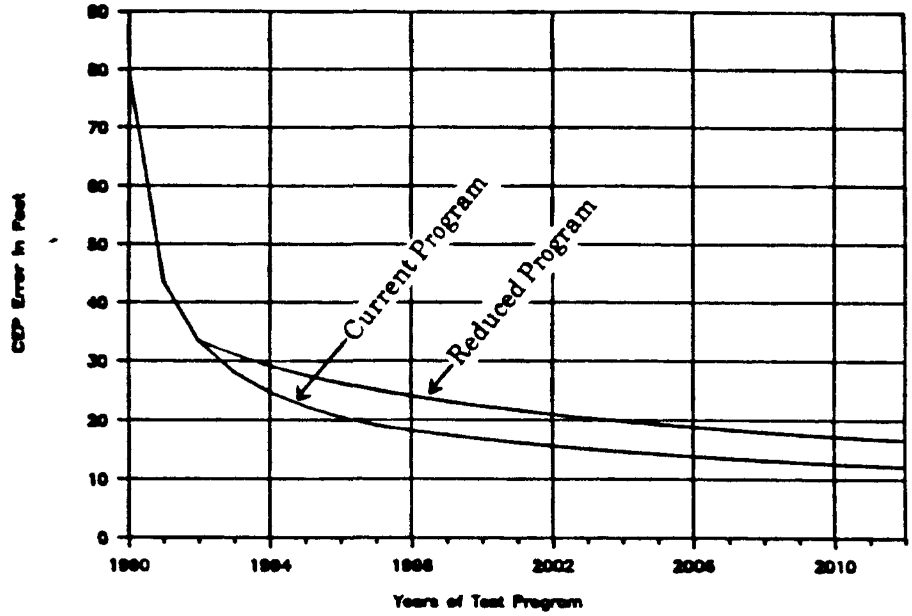

FIGURE II-A

EXPECTED ERROR IN SIOP CEP

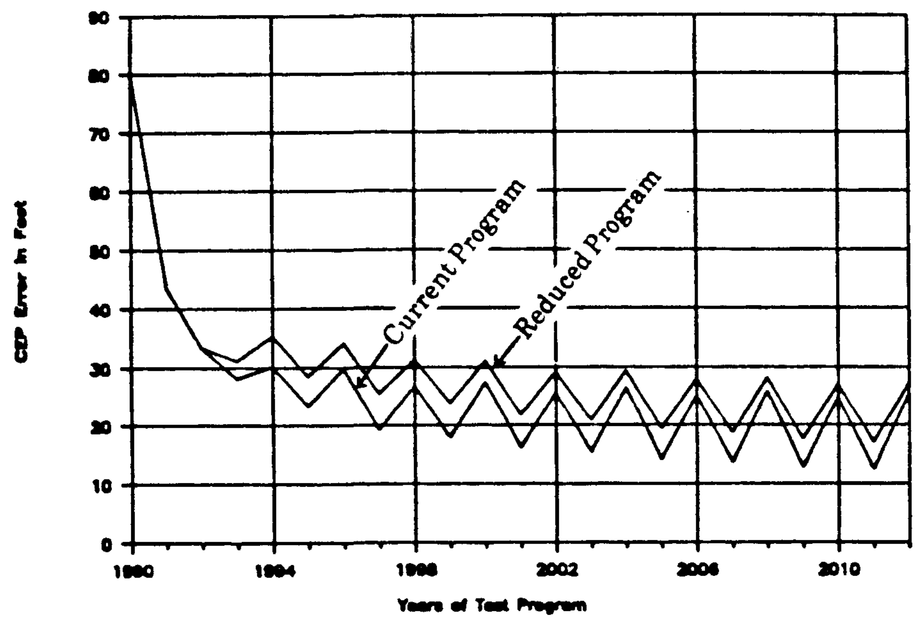

FIGURE II-B

NOTE: Figures II-A and II-B display the expected error in the estimates of CEP derived from two FOT programs. The current program consists of 16 missiles per year for five years and 12 missiles per year for fifteen years. The reduced FOT program consists of 6 missiles per year for twenty years.

In Figure II-A the true missile CEP is 500 feet throughout the life of the program. In Figure II-B the true missile CEP varies from 525 feet to 475 feet as problems develop and then are corrected. Both figures assume that the OT program has 40 missiles and that the annual CEP estimate is based on data from all previous missile tests.

from a single submarine within a short period of time--and to compensate for a variety of sea states, weather, and azimuths. Finally, the Trident II is being designed to carry two different reentry vehicles, the Mark IV and the Mark V, requiring the Navy to test missiles to establish the characteristics of each RV. 15/ These special operating requirements make it clear that the mission of launching SLBMs is significantly more complex than the mission of launching ICBMs.

It is not clear, however, that these special operating requirements demand additional FOT flight tests. First, before the initial FOT flight the Navy will have flown the Trident II as many as 70 times in the R&D and OT programs. These flights provide an extensive opportunity to document behavior of the missile under diverse operating conditions such as range, sea states, and other factors. 16/

Moreover, mathematical modelling and experiments that fall short of launching operational missiles contribute a great deal to understanding the operation of a SLBM under diverse conditions, reducing the data required from actual test flights. For example, although accuracy is degraded as missiles are launched sequentially during a ripple launch, mathematical models provide a good indication of the effect that the order of launch will have on the accuracy of the missiles. These models can then be checked by navigational data generated from ripple launches conducted in the course of a normal OT/FOT program. 17/ Similarly, mathematical modelling can complement flight tests in exploring the effects of azimuth, weather, and sea states on the missile's performance.

Finally, the experience with the Mark IV warhead in the Trident I program provides the Navy with a good foundation for calculating the performance of the Mark IV warhead in the Trident II program, thus reducing the testing demands that two different warheads impose.

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15. The two RVs will have different masses, drag coefficients, and ablation characteristics, all of which affect the performance of the RV when it reenters the atmosphere.

16. Of the 30 R&D flights, 20 will be from land and therefore will provide no information in regard to sea states. The flights will, however, provide substantial information on the missile's performance in regard to range, reentry angle, and reentry vehicles.

17. Also, the difference in accuracy between the first missile launched and the last missile launched is not large enough to affect significantly the probability that a warhead will destroy its target.

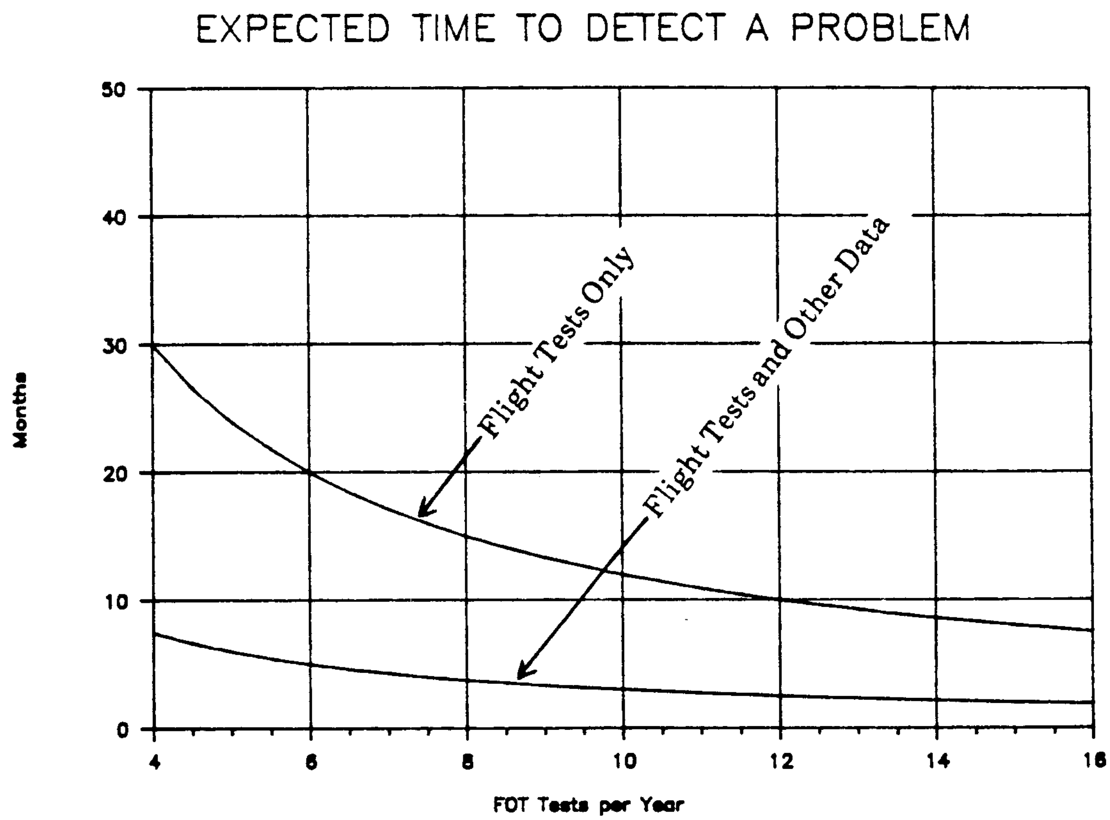
To summarize, in light of the data provided by the R&D program, the OT program, and mathematical modelling, there is no reason to believe that the task of charting Trident II performance necessitates annual FOT programs significantly larger than the level designed to provide good estimates for the SIOP performance parameters.

Problem Detection. To resolve an emerging problem in a missile force requires detecting the problem, analyzing the problem, and testing remedies. A problem can be detected through a failure or degraded performance during either flight tests or ground-based tests of components. Once the degraded performance is observed, however, the cause must be isolated. If the cause is obvious, it might be possible to design remedies after a single observation. More commonly, the cause of improper performance is not clear and additional testing is necessary to isolate it. Finally, after a problem has been isolated and a remedy designed, additional component tests and flight tests might be necessary to determine whether the remedy is effective.

Thus, the annual FOT level has a significant effect on each phase of problem correction: detection, analysis, and repair. As flight tests are reduced the time required for each phase will increase. For example, if a problem were to affect 10 percent of the missile force and if flight tests were the only method of detecting a problem, on average 10 flight tests would be required. Thus, the average time to detect a problem would be 10 months under a program of 12 tests per year and 20 months under a program of 6 tests per year (see Figure III). Additional time would be required to isolate the cause of the problem and to correct it.

The Navy is not, however, dependent solely upon flight test data to find a problem. Procedures that complement flight testing include ground-based tests of key components, electrical tests, inspections, and X rays of the motors. These tests, which are conducted regularly through the Navy's Fleet Return Evaluation Program, establish a significant probability of finding a developing problem independently of flight tests. If the battery of ground-based tests and inspections could detect three of four emerging problems--i.e., if 25 percent of the emerging problems could only be detected by flight tests--then on average approximately three test flights would be required, in combination with the ground-based tests and inspections, to observe a problem affecting 10 percent of the force. Thus, the average time to detect a problem would be approximately three months under a program of 12 tests per year and five months under a program of 6 tests per year (see Figure III).

FIGURE III



NOTE: This figure displays the average number of months required to detect an emerging problem affecting 10 percent of the missile force. The top line assumes that flight test data from the FOT program are the only available tool for detecting a problem. The lower line assumes that other tools--DASO flights, inspections, component tests and electrical tests--provide a 75 percent probability of detecting a problem independently of FOT data. After a problem is detected, additional ground-based tests and flight tests are often necessary to isolate the cause of the problem and to test remedies.

To summarize, a reduction in the FOT program from 12 to 6 tests per year would, depending on the value of ground-based tests and inspections, reduce by 2 to 10 months the average time required to detect an emerging problem affecting a small percentage of the force. A reduction in the FOT program might have an additional effect on the time required to isolate and correct a problem.

The DASO Program

In addition to the OT and FOT tests discussed above, the Navy has a third test program in which missiles are tested from ships going through Demonstration and Shakedown Operations (DASO) following construction or a major overhaul. The Navy plans to test two missiles from each of the first four ships that carry the Trident II. One missile will be tested from each subsequent ship that is constructed (eight ships) or backfitted (eight ships) to carry the Trident II. Finally, one missile will be tested after each submarine carrying Trident II missiles goes through a major overhaul (32 overhauls are planned). These tests account for the 56 missiles planned for the Navy program. 18/

DASO test flights have performed three distinct functions. First, DASO flights have been used traditionally to demonstrate that a nuclear ballistic missile submarine is fully capable of performing its task. As test procedures to determine whether a submarine is fully functional have improved, the value of this function has decreased considerably. Today a battery of tests and procedures give a submarine commander considerable confidence that his ship can perform as required without the confirmation provided by a DASO flight.

Second, DASO flights provide controlled conditions for isolating problems and testing remedies. DASO flights are superior to FOT flights for this purpose, for two reasons: in a DASO flight certain parameters such as currents, weather, and the precise location of the ship, are known with greater precision than in FOT flights, where a ship is on patrol by itself to

18. When a DASO test is conducted, three missiles are loaded aboard a submarine. These missiles, in combination with several "active inert missiles" (AIMs are concrete substitutes equipped with the electronics of a normal missile) enable the crew to practice aligning guidance systems and executing fire control procedures. After several weeks of training, one missile is launched by the crew. The other missiles are returned to shore to be dismantled and inspected. When needed, the parts will be employed in new or refurbished missiles.

simulate operational conditions. Also, since the attachment of certain test equipment or experimental parts would in many cases invalidate data collected on reliability or accuracy, it is best to avoid using such equipment or parts on FOT flights.

Third, when conducted in a manner that does not invalidate the data obtained, DASO flights provide additional information on parameters employed in the SIOP. This function is of most value in the first few years of a program when the OT/FOT data are fairly limited.

Of the three functions, the second--providing a more controlled environment--has become the strongest justification for DASO flights. Therefore, it would make sense to size the DASO fleet on the basis of the demand for more controlled tests rather than on the schedule of ship construction and overhaul.

CHAPTER III. ALTERNATIVES

Initial procurement of the Trident II missile is planned for fiscal year 1987. A decision to reduce the test program below the level proposed by the Administration could save at least $1 billion over the next five years and as much as $4 billion to $7 billion over the entire 13-year procurement program. Should the Congress choose to reduce the test program, however, effective implementation would require either a clear long-term ceiling on the number of test missiles or annual testing limits.

ALTERNATIVE 1: The Administration's Program

The Administration plans to procure a total of 356 Trident II test missiles (see Table II). As discussed earlier, this will provide enough missiles to assure a high probability of meeting JCS guidance in the OT program and of exceeding JCS standards in the FOT program. It will also provide the Navy's recommended level of DASO missiles, ensuring that each ship can demonstrate its capability to launch a missile following construction or a major overhaul. This program is expensive, however, costing about $14.0 billion.

ALTERNATIVE 2: A Moderate Test Program

The Congress could choose a more moderate test program than proposed by the Administration and still meet all the requirements of JCS guidance for OT and FOT programs. This alternative would reduce by 105 the number of test missiles procured over the life of the program, saving $1 billion in procurement over the next five years and $4.1 billion by fiscal year 1999 (see Table III).

Specifically, this alternative would reduce the number of OT missiles from 40 to 36, providing a 71 percent probability of meeting JCS guidance as opposed to a 90 percent probability under the Administration's plan. 19/

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19. This level of testing (36 missiles) is also the level originally proposed by the Air Force for the MX missile OT program. However, the Air Force subsequently decreased the size of the MX OT program to 25 missiles, shifting an additional 11 missiles into the MX missile FOT program. Although the Air Force, using a form of Bayesian analysis, has asserted that the MX OT program would still meet JCS guidance, the Bayesian

TABLE II. ALTERNATIVE PROGRAMS

	Administration Alternative	Moderate Alternative	Minimum Alternative
OT Program:			
Size	40 missiles	36 missiles	36 missiles
Probability of Meeting JCS Guidance a/	90%	71%	71%
Expected Error in Reliability Estimate a/	3.7 percentage points	4.0 percentage points	4.0 percentage points
FOT Program:			
Size	260 missiles	170 missiles	120 missiles
Expected Error in CEP Estimate b/	20 feet	23 feet	26 feet
Average Time to Find Emerging Problem c/	3-10 months	4-15 months	5-20 months
DASO Program:			
Size	56 missiles	45 missiles	25 missiles
TOTAL Program:			
Size	356 missiles	251 missiles	181 missiles
Cost d/	$14.0 billion	$9.9 billion	$7.3 billion

a. Assumes that true SLBM reliability is 90 percent.

b. Uses fiscal year 1996 as the reference year.

c. Assumes that the problem affects 10 percent of the missile force.

d. Since test missiles and deployed missiles are procured simultaneously, it is difficult to allocate the cost of each on a year by-year basis. The cost of the total test program--$14 billion--is based on the average cost per missile in current dollars times the number of missiles in the test program.

TABLE III: TRIDENT II PROCUREMENT COSTS a/
(By fiscal year)

Alternative	1987	1988	1989	1990	1991	Total 1987-1991	Total Program
Administration							
Quantity	27	66	66	66	72	297	844
Cost b/	1.9	2.5	2.6	2.6	2.5	12.1	32.8
Moderate Test							
Quantity	20	60	60	60	70	270	739
Cost b/	1.5	2.4	2.4	2.4	2.4	11.1	28.7
Savings c/	0.4	0.1	0.2	0.2	0.1	1.0	4.1
Minimum Test							
Quantity	20	60	60	60	60	260	669
Cost b/	1.5	2.4	2.4	2.4	2.1	10.8	26.1
Savings c/	0.4	0.1	0.2	0.2	0.4	1.3	6.7

a. All costs and savings are in billions of current year dollars.

b. The cost includes the procurement costs of all Trident II missiles (missiles that will be deployed as well as missiles that will be tested) and the costs of conducting flight tests.

c. Savings as compared to the Administration alternative.

Also, there would be an expected error in the SIOP reliability estimate of 4.0 percentage points as compared to 3.7 percentage points under the Administration's plan (see Table II).

This alternative also reduces the FOT program, providing 170 rather than 260 missiles. The 170 missiles would enable the Navy to conduct 10 FOT tests per year for five years and 8 tests per year for the following fifteen years. This level of testing is greater than required by JCS guidance (6 tests per year), retaining some program flexibility and augmenting the investigation of missile performance over diverse flight paths and operating environments.

This decreased FOT program would, however, have an adverse effect on establishing the reliability of a new component, estimating CEP, and detecting emerging problems. With fewer tests per year, the Navy would be dependent on data from ground-based tests for a longer period of time in estimating the reliability of new components. 20/ Also, the expected error in the SIOP CEP estimate would be 23 rather than 20 feet. 21/ This is an insignificant change, however, given the large warheads the Trident II will carry. Finally, the average time required to detect an emerging problem affecting 10 percent of the force would increase by as much as five months, a change that should have a modest effect on the retaliatory capability of the Trident II missile force. 22/

This alternative would base the DASO test program on the demand for highly structured test flights rather than on the schedule for ship construction and overhaul. By providing for two highly structured test

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analysis as employed by the Air force is flawed. See a CBO Working Paper, "The MX Missile Test Program," for a detailed discussion.

20. Ground-based testing of the component and experience with similar systems would serve as the basis for estimating component reliability until a substantial flight test record was established. This is similar to the way that reliability is estimated pending completion of the OT program.

21. This comparison is based on test results as of 1996. For comparisons in other years see Figure II.

22. An increase of five months (from 10 months under the Administration's plan to 15 months under this alternative) presents the most stringent case in which only flight test data are of use in detecting emerging problems. In reality, the battery of ground-based tests are of great use. If ground-based tests could detect three of four emerging problems, then this alternative would only make a one-month difference (four rather than three months) in the average period in which an emerging problem affecting 10 percent of the force was detected.

flights per year for 20 years and an additional five DASO missiles to meet special demands as they arise, this alternative would decrease by eleven the number of DASO tests required relative to the Administration's plan. Although based on the demand for structured test flights, this level of testing would allow the Navy to continue to test at least one missile from each new Trident submarine, each submarine refitted with Trident II missiles, and most Trident submarines completing major overhauls.

ALTERNATIVE 3: A Minimum Test Program

The Congress could choose to reduce the test program still further, providing only the minimum number of test missiles necessary to meet JCS guidance and a limited DASO program. Relative to the Administration's plan, this alternative would reduce Trident II procurement by 175 missiles, saving $1.3 billion over the next five years and $6.7 billion over the life of the program (see Table III).

Under this alternative, the OT program would be the same as outlined in Alternative II. The FOT program would, however, be limited to the minimum six flights per year necessary to meet JCS guidance. This reduction would require the Navy to rely more extensively on mathematical modelling and data collected during R&D, OT, and DASO flights to document the performance of the Trident II under diverse conditions. This alternative would also restrict the Navy's ability to establish quickly a flight-test record for the reliability of a new component.

In addition, the reduced FOT program would as in Alternative 2 adversely affect the CEP estimate employed in the SIOP and the speed with which problems are detected. Under this FOT alternative the expected error in the CEP estimate would increase to 26 feet and the average time to find an emerging problem would increase by up to 10 months. 23/ 24/

This alternative would also restructure the DASO program as proposed in Alternative 2, but the program would be limited to two flights per year

23. The expected errors in CEP are based on test results as of 1996. For figures based on other years see Figure II.

24. As before, the increase in the average time to find a problem (from 10 months under the Administration's plan to 20 months under this alternative) presents the most stringent case in which only flight test data are of use in detecting emerging problems. If ground-based tests could detect three of four emerging problems, this alternative would only make a two-month difference (five rather than three months) in the average period in which an emerging problem affecting 10 percent of the force would be detected.

for 5 years and one flight per year for the following 15 years. If emerging problems were to necessitate larger numbers of carefully controlled DASO flights, it would be necessary to equip some OT/FOT flights with additional instrumentation and conduct them under more controlled circumstances. This would, for some subsystems, compromise data that would otherwise be used in updating SIOP parameters. Although based on the demand for structured test flights, this DASO alternative provides enough missiles to allow the Navy to continue to test at least one missile from each new Trident submarine and each Trident submarine refitted with Trident II missiles.

Congressional Strategies

Whether the Congress chooses either the moderate or minimum test alternative discussed above, it should clearly establish a long-term ceiling on the test program or should set annual test limits. Otherwise, the Navy would not have clear guidance for restructuring the test program and might proceed with its current plan. Although the Navy would have enough missiles to proceed with its current testing plan under either the moderate or minimum alternative until 1994, it would have virtually none left for tests in the subsequent four years.

The Congress could prevent this potential problem in one of three ways. First, it could describe its chosen total procurement plan (1987-1999) in the authorization act and direct the Navy to adjust its testing schedule accordingly. While providing a solid foundation for planning the test program, this approach would leave the details of test planning--annual test levels and categories of testing--up to the Navy.

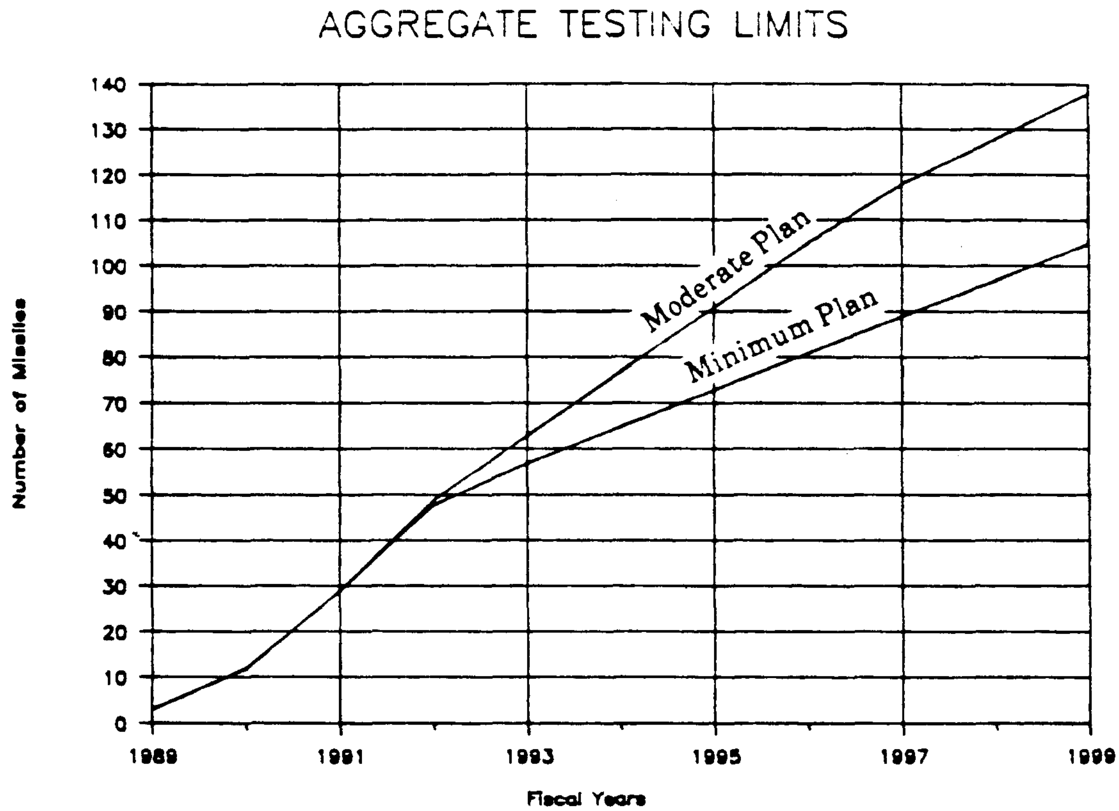
Second, the Congress could specify in the authorization act or in other legislation that no more than a specified aggregate number of the missiles could be tested during the current and prior fiscal years. For example, under the moderate alternative the Congress would allow the Navy to flight test up to 3 missiles by the end of fiscal year 1989, 12 by the end of fiscal year 1990, and 29 by the end of fiscal year 1991 (see Figure IV). This approach would effectively implement either the moderate or minimum alternative but would severely limit the Navy's flexibility in meeting unanticipated testing demands.

A third approach would be to identify procurement funding for test missiles as a separate line item and to authorize and appropriate the entire account in a single year. This approach, which is similar to the way a ship is funded, would be possible because the optimal number of test missiles is

essentially independent of the number deployed. By establishing the total size of the test program, this approach would provide a stable planning base while letting the Navy determine the optimal number of missiles to test by year and category. Also, this would permit the Navy to decide how many test missiles to produce each year in combination with missiles being produced for deployment, maximizing efficiency on the production line. 25/ The main disadvantage of this approach, of course, is that it would greatly inflate the 1987 authorization and appropriation accounts, possibly crowding out competing programs.

25. From the perspective of the production line and missile inventory there would be no difference between missiles for testing and for deployment. As is done currently, test missiles would be chosen at random from the deployed missiles, and stored missiles would be brought out to replace the tested missiles.

FIGURE IV



NOTE: This figure plots aggregate testing limits by fiscal year for the Moderate and Minimum alternatives. For example, under the Moderate Alternative the Navy would be allowed to flight test up to 63 missiles by the end of fiscal year 1993 and 91 missiles by the end of fiscal year 1995. Under the Minimum Alternative the corresponding figures would be 57 missiles and 73 missiles. As reflected above, the aggregate testing limits for the two programs would be identical for fiscal years 1989 through 1992 because the two alternatives have the same OT program.