
BY THE COMPTROLLER GENERAL

Report To The Congress

OF THE UNITED STATES

Status Of The Air Force's Missile X Program

The Air Force is developing a new, highly accurate, mobile intercontinental ballistic missile system, the Missile X system. It is expected to have increased chances of survival over the silo-based Minuteman system.

The budget for fiscal year 1979 did not include any funds for full-scale development of Missile X. This deferral should permit Defense to resolve the problems outlined in this report.





COMPTROLLER GENERAL OF THE UNITED STATES
WASHINGTON, D.C. 20548

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To the President of the Senate and the
Speaker of the House of Representatives

This report presents our views on the major issues of the MX Intercontinental Ballistic Missile Program. A draft of this report was reviewed by agency officials associated with the program and their comments are incorporated as appropriate.

For the past several years we have annually reported to the Congress on the status of selected major weapons systems. This report is one of a series of reports that we are furnishing this year to the Congress for its use in reviewing fiscal year 1979 requests for funds.

We made our review pursuant to the Budget and Accounting Act, 1921 (31 U.S.C. 53), and the Accounting and Auditing Act of 1950 (31 U.S.C. 67).

We are sending copies of this report to the Acting Director, Office of Management and Budget, and the Secretary of Defense.


Comptroller General
of the United States

D I G E S T

The Missile X (MX) system is an advanced, highly accurate, mobile intercontinental ballistic missile system the Air Force is starting to develop. Its increased survivability, as compared to the fixed-in-place Minuteman system, is intended to be gained by having a number of possible missile launch points. In this way, an enemy would be unable to identify the exact location of the missile before launch. Compared to Minuteman III, Missile X is also intended to be more accurate and capable of delivering a larger number of nuclear warheads.

The Air Force is considering buried trench and shelter basing concepts for deployment of the MX.

The buried trench concept consists of shallow-buried concrete tubes. The missile, on a transporter, with launch and control equipment, is randomly moved within the tube. This prevents learning the location of missiles by acoustic, optic, thermal, magnetic, or electronic sensors. The enemy must attack the entire trench to have a high confidence of destroying the missile. The trench structure protects the missile and equipment from external pressure and other effects of a nuclear weapon detonation. Blast plugs located on either side of the missile provide protection from internal pressure caused by a nuclear detonation breaking the tube. For firing, the missile is elevated in its canister through the tube and the earth cover.

The shelter concept is based on moving a missile, with launch and control equipment, between a number of hardened shelters. An enemy must successfully attack all shelters to be sure that the one containing the missile is destroyed. The shelter provides protection against air blast and radiation, and the launch

equipment and canister provide protection from electromagnetic pulse and ground shock. The missile may be moved outside the shelter and elevated to a vertical position for launch, or it may be designed to break through the roof, as in the trench concept.

The MX program is in the validation phase of advanced development. During this phase the Air Force is proving missile technology and mobile basing concepts to reduce technical risks and cost uncertainties. At the conclusion of the current phase, the Air Force is expected to have defined a baseline MX system for full-scale development.

The current status of the validation activity for full-scale development of the MX system follows.

- All program estimates are tentative at the present time. Before meaningful estimates can be prepared, the quantity of missiles must be determined, the baseline missile defined, and the basing mode selected. (See p. 5.)
- The Air Force developed MX program cost estimates for planning purposes. One planning estimate showed a cost of about \$28 billion for a 200-missile force. (See p. 5.)
- Advanced development of the MX system was estimated to cost \$316 million. (See p. 4.)
- The MX schedule plan shows full-scale development beginning in November 1978 and production in June 1983. Funding, however, was not included in the fiscal year 1979 budget for full-scale development of MX. (See p. 6.)
- Performance thresholds have been established, but MX performance specifications will not be established until full-scale development approval. (See p. 6.)

- Missile basing has been narrowed to two generic concepts--buried trenches and shelters. (See p. 1.)
- The MX program office currently is investigating 11 technical or cost risk areas defined in the MX Decision Coordinating Paper. (See p. 7.)
- Air Force officials are generally satisfied with results in missile risk areas. However, for one area--directional rocket motor nozzle technology--test results have not been totally successful. Although two experimental nozzles failed during testing, program officials expressed confidence that technical risk for the directional nozzle area has been reduced. Tests conducted were more severe than tests planned for the MX nozzles. (See p. 7.)
- The Air Force plans to construct two trenches to evaluate trench basing costs, production rate and schedule estimating, and construction technology. (See p. 11.)
- Final data from several risk efforts will not be available until October 1978, and complete data on tunnel construction not until spring 1979. However, the Air Force expects the necessary data to support full-scale development in advance of these dates. (See pp. 11 and 12.)

The Air Force MX program office has been active in efforts to reduce technical and cost risk for the MX program. Most work to date showed positive results.

Problems identified during validation, but mainly delays in having complete data needed to define the most cost-effective system to meet MX operational requirements, make deferring full-scale development beyond November 1978 advisable.

A draft of this report was reviewed by program officials. Their comments were incorporated as appropriate.

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ABBREVIATIONS

GAO	General Accounting Office
ICBM	intercontinental ballistic missile
MX	Missile X

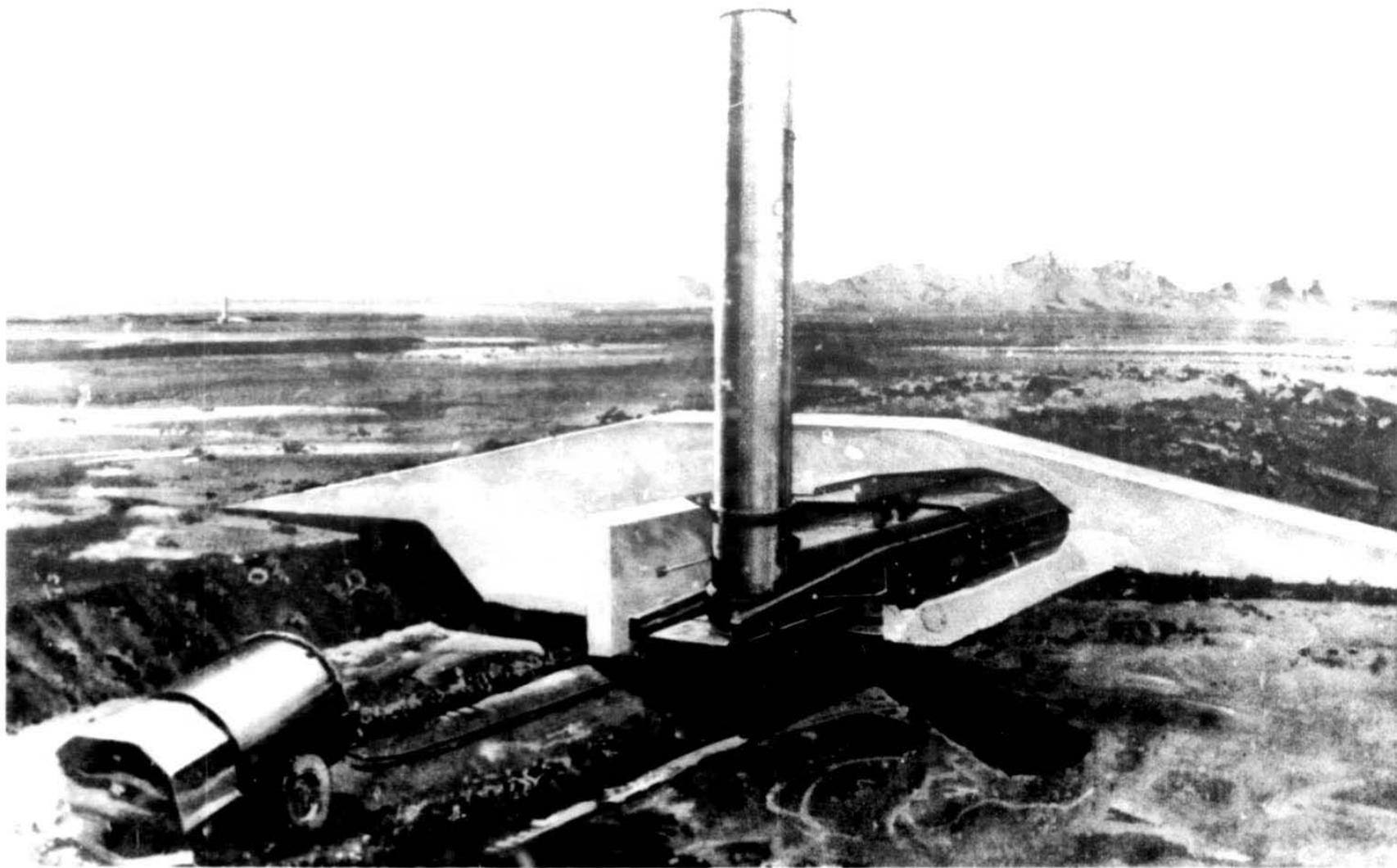


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SHELTER CONCEPT



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BURIED TRENCH CONCEPT

CHAPTER 1

INTRODUCTION

The U.S. strategic nuclear forces are embodied in a triad of strategic systems; namely land-based intercontinental ballistic missiles (ICBMs), manned bombers and cruise missiles, and submarine-launched ballistic missiles, called the TRIAD system. Each element of the TRIAD force provides deterrence. ICBM combines accuracy, flexibility, early time-on-target, a high alert rate, positive command and control, and economy of operations. Because of these characteristics, ICBMs can be applied across the entire target spectrum and constitute the best capability against targets resistant to nuclear attack.

The Air Force sees a need to modernize the ICBM force in terms of improved survivability and effectiveness. The essence of survivability rests on the ability to absorb a first strike and retaliate with the appropriate force. ICBMs in silos are considered survivable today, but they will become vulnerable as the accuracy of the enemy's ballistic missiles improve and increased numbers are deployed. The Air Force proposes multiple aimpoint basing to maintain high missile survivability against increased threats by making it more difficult for the enemy to identify the exact missile location before attack and by making the missile resistant enough to survive conceivable attacks.

At the same time, the Air Force is expanding the technology for developing an improved ICBM--one capable of carrying a larger payload.

Missile X (MX) is perceived as an increased throwweight, survivable, and highly accurate ballistic missile with a multiple independent retargetable reentry vehicle capability. The Air Force is considering buried trench and shelter basing concepts for missile deployment. Both concepts involve proliferation of hardened aimpoints through concealed movement of a missile to any one of a number of possible locations.

The buried trench concept consists of shallow-buried concrete tubes. The missile, on its transporter with launch and control equipment, is randomly moved within the tube. This prevents unauthorized location of most missiles by acoustic, optic, thermal, magnetic, or electronic sensors. The enemy must attack the entire trench to have a high confidence of destroying the missile. The trench structure

protects the missile and equipment from external pressure and other effects of a nuclear weapon detonation. Blast plugs located on either side of the missile provide protection from internal pressure caused by a nuclear detonation breaking the tube. For firing, the missile is elevated in its canister through the tube and the earth cover. The missile is launched at about 45-degree angle.

The shelter concept is based on moving a missile, with launch and control equipment, between a number of hardened shelters. An enemy must successfully attack all shelters to assure that the one containing the missile is destroyed. The shelter provides protection against air blast and radiation, and the launch equipment and canister provide protection from electromagnetic pulse and ground shock. The missile may be moved outside the shelter and elevated to a vertical position for launch, or it may be designed to break through the roof, as in the trench concept.

MX DEVELOPMENT PROGRAM HISTORY

The advanced development program for the MX missile was started in 1974. Since then, operational capability requirements have not changed. However, missile basing has undergone several changes. The Air Force initially planned to deploy the first missiles in existing Minutemen silos; later missile deployment was to use one of several optional mobile basing modes. Toward this end, the feasibility of launching an ICBM from an aircraft was demonstrated in October 1974. Later, equal emphasis was directed toward defining ground mobile and silo-based concepts. However, the Congress stopped funding the silo-based concept.

When MX was approved for advanced development, the Air Force planned to start full-scale development in fiscal year 1978. Subsequently, when the validation phase was approved in 1976, full-scale development was planned for September 1977. With the advent of a new administration, the program was restructured in April 1977 to accommodate beginning full-scale development in fiscal year 1979.

At the present time advanced development of the missile and of the trench and shelter options are being continued.

MX PROGRAM MANAGEMENT

The Deputy for Intercontinental Ballistic Missiles, Space and Missile Systems Organization (SAMSO), Norton Air Force Base, California, is responsible for managing the MX program. The program office integrates industry efforts to support the MX development program.

The program office has contracted with the Defense and Space Systems Group of the TRW Corporation for systems engineering and technical direction of the validation and system definition support. Program support involves (1) design, improvement, and overall technical advances in weapon system reliability and effectivity and (2) preparation of preliminary specifications and contract work statements.

SCOPE OF REVIEW

This is our first review of the MX program's status; we reviewed the program as of December 31, 1977. The primary objective of this review was to determine the cost, schedule, and performance status of the missile development and mobile basing program elements, especially the extent to which technical risks and cost uncertainties were being assessed during the validation phase. We reviewed contract work statements, program management and planning documents, technical reports from associate contractors, test reports, program cost estimates, milestone schedules, and held discussions with program officials.

CHAPTER 2

STATUS OF THE MX PROGRAM

The MX program is in the advanced development phase of the acquisition cycle. Missile technology and mobile basing concepts are being validated to reduce technical risks and cost uncertainties in preparation for an October 1978 decision on full-scale development.

Delays in cost validation efforts may make deferring the decision advisable. In addition, nozzle assembly failures occurred during rocket propulsion tests. Program officials expressed the view that work in the nozzle technology area has reduced technical risk. (See ch. 3.)

Firm cost estimates, schedule milestones, and performance goals were not established at the time of our review; however, program officials provided us with planning data as a tentative program baseline. Firm cost, schedule, and performance baseline estimates will be developed by the time a full-scale development decision is made. The estimates will be based in large part on the results of the validation phase.

MX COST ESTIMATE

The Air Force estimated that advanced development will cost about \$316.3 million. A breakdown of estimated advanced development cost by functional area and fiscal year is as follows:

Functional area	Cost (millions)				
	1974 to 1977	1977	1978	1979	Total
Air mobile basing	\$ 7.5	\$ -	\$ -	\$ -	\$ 7.5
Propulsion	32.3	5.8	12.9	4.5	55.5
Performance and software	2.8	1.0	2.8	.3	6.9
Guidance and control	43.8	21.8	29.0	6.5	101.1
Command/control/communications, physical security, and ground power	.1	2.7	7.0	.7	10.5
Missile transport and launch vehicles	.7	9.3	13.6	.2	23.8
Canister	2.5	1.3	1.1	.6	5.5
Buried trench	-	4.7	16.0	-	20.7
Shelter closure	-	5.2	2.7	-	7.9
Siting/shelter/design	2.2	5.6	4.0	.6	12.4
Environment	-	1.7	4.4	-	6.1
Vulnerability and hardening	.1	5.4	6.8	1.0	13.3
System engineering/management support	.9	4.5	32.1	4.1	41.6
Reentry vehicle	-.1	-.1	2.0	1.5	3.5
Total	<u>\$92.9</u>	<u>\$69.0</u>	<u>\$134.4</u>	<u>\$20.0</u>	<u>\$316.3</u>

Acquisition cost

Estimates for the acquisition cost of the MX system are very tentative. The number of missiles to be deployed has not been established, and the mobile basing mode with associated transport and launch equipment has not been selected. Further, missile configuration has not been defined, including all aspects of the propulsion, guidance and control, and reentry vehicle subsystems. In addition, land requirements and environmental issues could affect program cost estimates.

For planning purposes, the Air Force prepared cost estimates based on different missile quantities and basing assumptions. The following is a planning estimate based on deploying 200 missiles, each in a 12-mile trench on public domain land withdrawn for Defense use.

MX Acquisition Planning Cost Estimate

	<u>1976</u> <u>dollars</u>	<u>Then-year</u> <u>dollars</u>
	(millions)	
Development	\$ 4,963.0	\$ 7,430.8
Procurement	7,296.6	13,571.3
Military construction	<u>3,831.1</u>	<u>7,258.0</u>
Total	<u>\$16,090.7</u>	<u>\$28,260.1</u>

Based on the above, the program unit cost would be about \$80 million per missile in 1976 dollars or \$141.3 million in then-year dollars.

MX SCHEDULE STATUS

The Air Force has developed the following tentative schedule milestones leading to production of the MX system.

<u>Milestones</u>	<u>Current estimate (10/31/77)</u>
Missile:	
Contract awards--full-scale development	11/78
System design review	2/80
Preliminary design review	11/80
Critical design review	1/82
First flight test	3/82
First flight test with vehicle	4/83
Production release	6/83
Multiple aimpoint basing:	
Contract awards for ground vehicles-- full-scale development	7/79
System design review	2/80
Preliminary design review	2/81
Critical design review	1/82
First multiple aimpoint flight test	4/83
Production release	6/83
Facilities:	
Final environment statement for support of full-scale development decision	7/78
Submittal of initial military construc- tion proposal	4/79
Final environmental statement for site selection	11/79
Selection of deployment area	12/79
Final environmental statement for mis- sile deployment	1/82
Commencement of construction	6/83

A recent decision by the Executive Department will delay the above schedule. Funding for MX full-scale development was not requested in the fiscal year 1979 budget. The Secretary of Defense said the basing concepts had not been sufficiently determined in terms of cost, survivability, or geographic location. He indicated that if these issues are resolved in time to allow a full-scale development decision in early fiscal year 1979, then any additional funding needed would be requested.

MX PERFORMANCE STATUS

Performance thresholds for accuracy, range, and throw-weight are included in MX planning documents, but performance specifications have not been established. Performance specifications at the system and subsystem level will be prepared during the remainder of the validation phase as a basis for detail design and development during the full-scale development phase.

CHAPTER 3

STATUS OF MX ADVANCED DEVELOPMENT

The Air Force has two major tasks to perform during advanced development of the MX. First, it must validate technical concepts and related cost estimates (this effort is referred to as validation). Second, based on the results of the validation effort, the Air Force must define the MX system for full-scale development. System definition should provide the most cost-effective life cycle cost configuration of missile and basing modes that supports operational requirements.

The major effort to date for MX advanced development has been in validation.

MX VALIDATION

The validation phase for the MX program includes a continuation of validation of key missile technology and basing concepts. The MX Decision Coordinating Paper identified 11 areas to be examined during the validation phase in order to reduce technical risk and cost uncertainties. Missile technology efforts focus on the propulsion, guidance and control, and reentry vehicle systems. The subsystems being validated and tested for multiple aimpoint basing include the buried trench and shelter closure concepts.

The status of the key areas are as follows.

Missile technology

First stage movable nozzle

The Air Force is evaluating a movable nozzle to be used on the first stage rocket motor. The movable nozzle is needed to achieve large and rapid changes in the missile's velocity and direction. This technology is important to achieving maximum payload and range for nonvertical missile launches contemplated with the buried trench basing mode and also to minimizing propellant energy for proper missile trajectory.

A contract was awarded in May 1974 for the design and test of the directional nozzle concept. Two of three scheduled tests were completed in December 1976 and September 1977.

In the first test carbon phenolic and two-dimensional carbon/carbon material eroded from the side of the nozzle inlet when the nozzle was vectored about 14 degrees (the maximum deflection for air-launched application, which has since been eliminated) into the gas flow stream. The failure occurred after about 10 seconds of a 60-second test firing. Shortly thereafter other portions of the nozzle failed as a result of the initial material failure. Analysis of the test results showed that the movable nozzle concept performed as predicted. However, the Program Office recommended reducing the vector angle commensurate with the intended application, increasing the thickness of the backside insulation material, and using an advanced integral throat entrance section made of carbon/carbon material for future tests.

The second test resulted in a failure of the exit cone. Test result analysis indicated that the exit cone broke away from the nozzle assembly during an 8-degree vector angle after approximately 35 seconds of the scheduled 60-second test, causing other portions of the nozzle assembly to fail. Program officials said that the integral throat entrance section and backside insulation would have satisfactorily completed the test had the exit cone not failed.

A third test scheduled for April 1978 has been cancelled because program officials considered all primary objectives of the program to be successfully completed. The scheduled test was to test a carbon/carbon exit cone. Program officials said that they did not consider the development mandatory because of proven ablative ¹/ exit cone technology.

A competitive nozzle design contract was awarded to a second contractor in August 1977; a test of this nozzle design is scheduled for June 1978. The Air Force also plans to award a development contract in March 1978 for advanced carbon/carbon materials for fabricating nozzles.

According to Air Force officials, knowledge gained in the two advanced development tests has better defined anticipated operating conditions and has helped in selecting reliable approaches for full-scale development. Consequently, the overall risk in the nozzle area was reduced.

¹/Ablative--a material that vaporizes or evaporates to dissipate heat.

Second stage motor

The Air Force is evaluating rocket motor design areas-- including high-energy propellant, high-strength case material, a lightweight nozzle, the thrust vector control, and an extendable nozzle exit cone for the second stage motor. A contract for the motor development program was awarded in May 1974.

Evaluation tests conducted in December 1976 verified performance requirements for the propellant.

Burst tests of two motor cases conducted in August and September 1977 resulted in case bursts at lower stress limits than the advanced development goal. Program officials stated that the lower stress limit burst results still provide increased case strength over previous designs and exceed the goals established for the full-scale development program.

A full-scale second stage motor (including the nozzle and thrust vector control) was successfully test fired in January 1977.

The extendable cone provides for higher energy efficiency and greater thrust. The operational capability and the structural integrity of the extendable cone was demonstrated during tests conducted in June 1976 and December 1976.

Third stage motor

The Air Force is evaluating designs for high performance propellants, a low length-diameter motor case, and an early motor thrust termination capability for the third stage motor. A contract for a demonstration program was awarded in September 1974.

The processing and mechanical properties for the propellant are satisfactory, and the performance characteristics for the propellant have been evaluated at sea level and simulated altitude conditions.

The demonstration of the motor case design and early thrust termination capability was successful. A full-scale test of a third stage demonstration test motor in August 1977 indicated that the demonstration program objectives were met. However, a nozzle failure occurred, resulting

in manual thrust termination. An evaluation of the malfunction disclosed a structural failure of the throat retainer.

The Air Force awarded two contracts in November 1977 for development of expandable exit cone technology for use on the third stage and possibly the second stage motor. The contracts are for low-cost techniques; three test firings are planned under each contract, the first of which is scheduled for October 1978.

Inertial measurement unit

The development of the Advanced Inertial Reference Sphere inertial measurement unit is critical to the accuracy of the MX system. Development includes complete radiation hardening; improvements in reliability, maintainability, and performance; and enhanced producibility.

A contract was awarded in May 1975 for the design, fabrication, system integration, and testing of the Advanced Inertial Reference Sphere. Four units are scheduled for delivery between January 1978 and April 1979, after completion of acceptance and quality configuration testing. Further verification testing will be performed for system definition and full-scale development. Verification testing for the first three units is scheduled for completion in July 1978. Complete program testing (including studies and evaluation) is scheduled for completion in April 1979.

A design review of the Advanced Inertial Reference Sphere was held in December 1977. The results showed that program objectives were being achieved. Three systems had been assembled at the time, and technical risks were sufficiently reduced to warrant a recommendation to proceed into full-scale development.

Reentry vehicle nosetips

The Air Force is evaluating the use of carbon/carbon material to reduce reentry vehicle flight errors to acceptable levels.

The development program included flight tests with carbon/carbon nosetips on a Minuteman missile. Test results showed a significant increase in accuracy when compared with

prior flight tests using carbon phenolic nosetips. In addition, two flight tests of reentry vehicles under development for the Minuteman missile indicated that the carbon/carbon nosetips will support required loads and enhance accuracy.

Additional flight tests are scheduled for 1978.

Potential use of the Global Positioning System

The Air Force objective of improving the accuracy of the MX system includes consideration of the potential use of the Global Positioning System, a satellite-based radio navigation system currently under development. Program officials stated that the Global Positioning System is not required for an operationally deployed MX system, but that some potential exists for its use during MX flight tests.

The Navy plans to use the Global Positioning System for flight testing in its Trident accuracy improvement program.

Basing modes

Demonstration of buried trench concept

The Air Force proposes to construct two underground tunnels to verify cost and time estimates, and construction technology for the buried trench concept. The tunnels will be full size (having an inside diameter of 13 feet) and will be buried approximately 5 feet below ground level. A construction contract was awarded in March 1977 to provide information on both a precast and a cast-in-place method.

For the precast method, a 1,500-foot trench will be constructed from 30-foot sections transported to the trench site. This trench will also be used to demonstrate mechanisms for breaking through the roof of the trench for a missile launch. The trench is expected to be constructed during March and April 1978.

For the cast-in-place method, a 20,000-foot trench (comprised of two 10,000-foot sections) will be constructed. Casting machines with the concrete poured in continuous process will be used. One 10,000-foot section will be constructed using existing construction equipment, whereas specially designed equipment will be used on the second section. Construction is scheduled for completion in late December 1978.

Program officials stated that the information obtained from the construction demonstration project would not be completely evaluated until February 1979. However, Air Force officials believe that sufficient evaluation will be available for a basing decision by the end of calendar year 1978.

Roof breakout mechanism

The Air Force is evaluating various mechanisms for breaking the launch equipment and missile through the roof of a buried trench for missile launch. Awards were made to two contractors in December 1976 for alternative designs and for fabrication of prototypes.

Both contractors will demonstrate units in a buried trench to be constructed for demonstration at Luke Air Force Base in Arizona. The contractors will provide reports on the results of tests scheduled for completion in July and August 1978.

Shelter closure

The Air Force is evaluating a closure assembly for the shelter. The closure assembly must be capable of providing ingress/egress for the missile launch vehicle, transporter, and launch control center. A contract was awarded in December 1976 for the design and fabrication of test models of the closure assembly.

The contractor completed the closure design and is fabricating models--one of which will be tested by the Air Force Weapons Laboratory in April 1978. Other tests are scheduled for completion in September 1978.

Protection of the missile and launcher

The Air Force and the Defense Nuclear Agency are conducting test programs to assess the nuclear hardness and survivability of the shelter and buried trench concepts. The tests will provide data for facilities design and assist in resolving technical and cost issues. The tests were started in October 1976 and are scheduled to be completed in October 1978.

Five of seven tests on subscale shelters and trenches have been completed. The tests are to determine structural loads and responses to simulated nuclear blast and shock

effects. Eight of 10 tests to determine the cumulative effects of ground shock on trenches from single and multiple high explosive detonations have also been completed. Additional MX-related tests include underground experiments to determine blast shock physics and the effects of electromagnetic pulse from nuclear weapons detonation.

Preliminary analysis of completed tests indicate that useful information is being obtained for the two mobile basing concepts. Program officials stated that the tests will be useful in making future decisions on the mobile basing concepts.

Environmental impact statements

The Air Force is preparing statements assessing the environmental consequences at key decision points for the MX system. Environmental statements have been, or will be prepared for (1) a buried trench construction and validation test project, (2) the decision for approval for full-scale development, (3) site selection, including a request for funding of military construction, and (4) deployment, including award of production and construction contracts. A contract was awarded in January 1977 for the preparation of the environmental statements.

A draft environmental impact statement for the buried trench test project was released to the public and government agencies in August 1977; the final report was released in January 1978.

The draft environmental statement to support the decision for full-scale development is being prepared. The final statement is expected to be released in October 1978.

The environmental statements for site selection and deployment are scheduled for release in September 1979 and January 1982, respectively.

CONCLUSIONS

Complete data may not be available to support an October 1978 MX full-scale development decision review. When concept validation was approved in 1976, the Air Force was tasked to reduce the magnitude and uncertainty of cost for critical MX subsystems and to demonstrate technical feasibility. For several areas specified for examination, information in the form of final contractor reports will not be available

until October 1978. In at least one major area (cost of constructing the buried trench) information will not be complete until well after October. The results of these efforts must be evaluated to propose the most cost effective design to meet operational requirements.

The Air Force feels that the quantity and quality of technical and cost data acquired during the MX advanced development program will be sufficient to support a full-scale development decision at the end of calendar year 1978.

Considering the cost magnitude and technical risks involved in the MX program, we believe that delaying full-scale development of the MX program is prudent and that scheduling the full-scale development decision should be contingent on the availability of accurate and complete results of advanced development efforts.

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