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BY THE COMPTROLLER GENERAL

Report To The Congress

OF THE UNITED STATES

NAVSTAR Should Improve The Effectiveness Of Military Missions--Cost Has Increased

The NAVSTAR Global Positioning System program, which is being developed for precise worldwide navigation and position capability, has increased in cost from about $1.7 billion to $8.6 billion.

This is due largely to estimates not previously included for replenishment satellites, launches, and user equipment.

Extensive testing proved that NAVSTAR may provide accurate navigation and position information. However, its potential problems relating primarily to Soviet threat, satellite reliability, and launch capability could have serious cost, schedule, or performance implications.

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UNITED STATES GENERAL ACCOUNTING OFFICE

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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 concerning the development and military applications of the NAVSTAR Global Positioning System. Agency officials associated with the program reviewed a draft of this report, and their comments have been incorporated as appropriate.

For the past several years, we have reported annually to the Congress on the status of selected major weapon systems. This report is one in a series that is being furnished to the Congress for its use in reviewing fiscal year 1981 requests for funds.

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

Elmer B. Staats
Comptroller General
of the United States

COMPTROLLER GENERAL'S REPORT TO THE CONGRESS

NAVSTAR SHOULD IMPROVE THE EFFECTIVENESS OF MILITARY MISSIONS--COST HAS INCREASED

D I G E S T

The NAVSTAR Global Positioning System has recently demonstrated that it can provide significantly more accurate navigation data than any current navigation system, is not deterred by adverse weather conditions, and has the potential to improve certain weapons delivery and coordinated operations.

However, this space-based radio system, designed to provide users with three-dimensional position measurements in addition to time and velocity, has some unresolved problems which could have substantial implications. For example, current Soviet testing of an anti-satellite system could eventually result in a weapon which could threaten the survivability of our forces. The Department of Defense (DOD) should closely monitor this emerging Soviet threat and continue to assess its impact in developing and planning the NAVSTAR system. (See p. 9.)

Another problem with the satellite's reliability emerged during the demonstration and validation phase when 80 percent of its atomic clocks turned on in space either failed or acted abnormally. If the clocks do not operate properly, military users may not obtain the accurate navigation and position information needed. Solutions may have been found; however, they cannot be confirmed until the clocks operate reliably in space. Alternative solutions could cost millions of dollars. (See pp. 9 to 11.)

Beginning in 1983, DOD plans to use the Space Shuttle to launch the operational NAVSTAR satellites. However, Space Shuttle problems could delay its availability for supporting NAVSTAR and thus jeopardize a fully operational NAVSTAR by September 1987. Atlas or Titan boosters as an alternative could cost an additional $12 million to $38 million for each satellite launch as compared to projected Space Shuttle launch costs. (See pp. 11 and 12.)

Acquiring and maintaining the NAVSTAR system through the year 2000 will cost an estimated $8.6 billion. Though significantly greater than reported previously, the current estimate includes several items that had not been included earlier such as Space Shuttle launch costs, user equipment procurement, and replenishment satellites.

Because the cost of NAVSTAR far exceeds any expected savings from reducing DOD's use of other systems, NAVSTAR's implementation depends heavily on the benefits provided by its increased navigational accuracy, global coverage, and other characteristics. Numerous DOD studies indicate that NAVSTAR should improve the effectiveness of military missions. (See pp. 17 and 18.)

GAO's January 1979 NAVSTAR report indicated that NAVSTAR development was not started to satisfy unmet military needs or operational deficiencies but rather to generally improve navigation capabilities. Despite the lack of specific user needs, DOD had estimated there were many military users who would need NAVSTAR capabilities. Since then, however, the services have defined specific mission requirements for improved navigation accuracies which are not met by any current navigation system or combination of systems. With few exceptions, these requirements will be satisfied by NAVSTAR.

A draft of this report was reviewed by agency officials associated with the management of the program, and their comments have been incorporated as appropriate.

Contents

ABBREVIATIONS

DOD	Department of Defense
GAO	General Accounting Office

CHAPTER 1

INTRODUCTION

The Department of Defense (DOD) has been developing the NAVSTAR Global Positioning System since 1973. NAVSTAR is planned to be fully operational in 1987 to meet future military navigation and position requirements by providing users accurate navigation data worldwide. In August 1979 the Secretary of Defense authorized the NAVSTAR program for full-scale engineering development during which an operational prototype system will be designed, built, and tested.

Although NAVSTAR is being developed as a military system, it has the potential to provide navigation and position information to civilian users as well. Possible benefits from using NAVSTAR instead of current navigation systems include more efficient use of airspace, increased safety, and improved airport use. DOD's position is to support the broadest possible civil use of NAVSTAR while preventing adverse exploitation detrimental to the security of the United States and its allies. This report primarily addresses military applications of NAVSTAR. Appendix I lists the reports we have issued regarding NAVSTAR, two of which discuss NAVSTAR's potential to replace civilian navigation systems.

SYSTEM DESCRIPTION

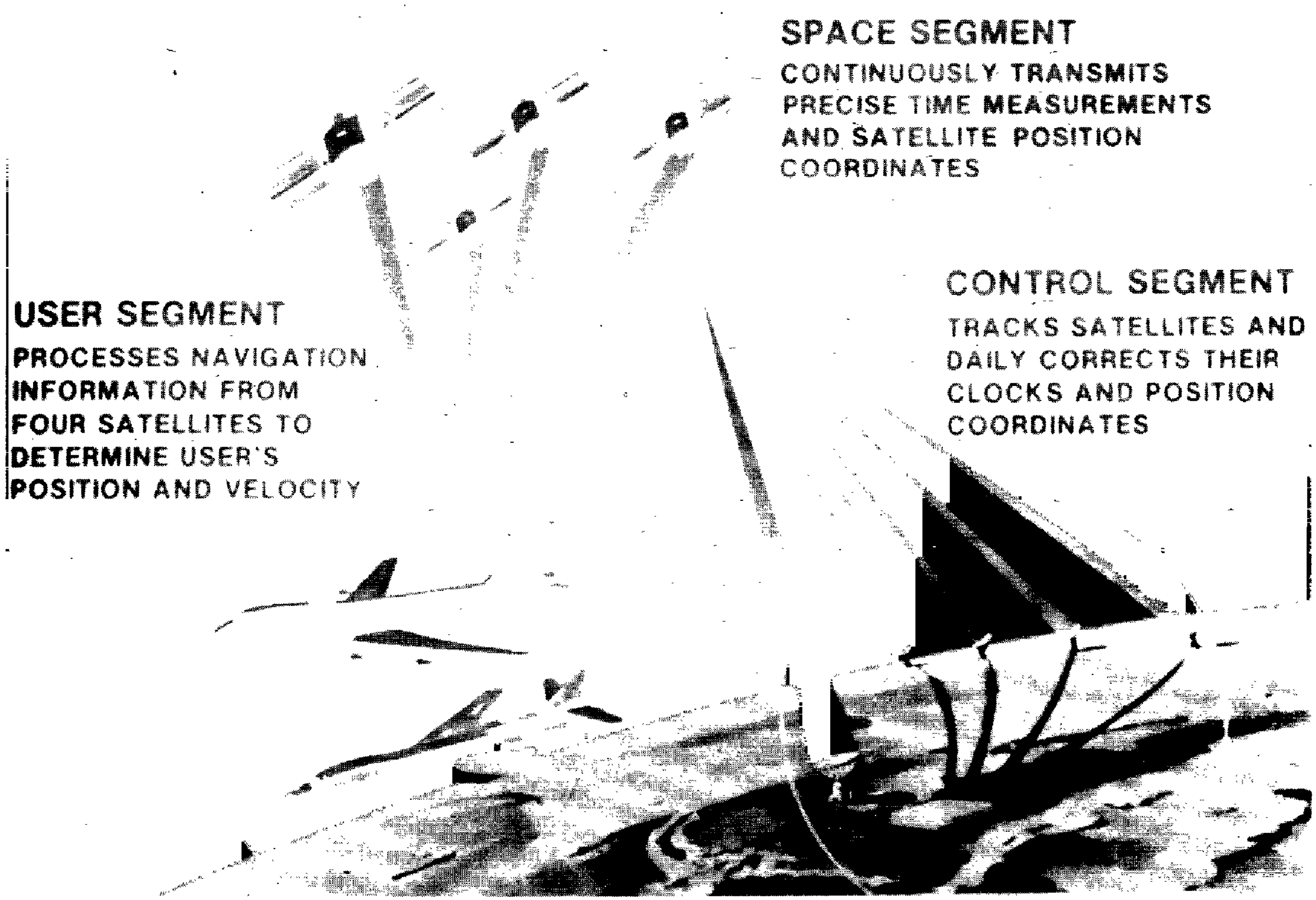
NAVSTAR is a space-based radio navigation system that will provide users with three position dimensions (latitude, longitude, and altitude), in addition to velocity and time. The information will enable continuous worldwide navigation under adverse weather conditions and, more importantly to the military, may significantly improve weapons delivery and coordinated operations.

As illustrated in figure 1 (see p. 2), NAVSTAR consists of three major segments. As shown in figure 2 (see p. 3), the space segment consists of 24 satellites placed in 3 circular orbits, 20,450 kilometers from the Earth. The satellites will continuously transmit their position coordinates and time.

The control segment includes all the ground facilities necessary to support the orbiting satellites. Satellite support includes daily updating the information broadcasted by the satellites and monitoring the functional condition of the satellites.

FIGURE 1

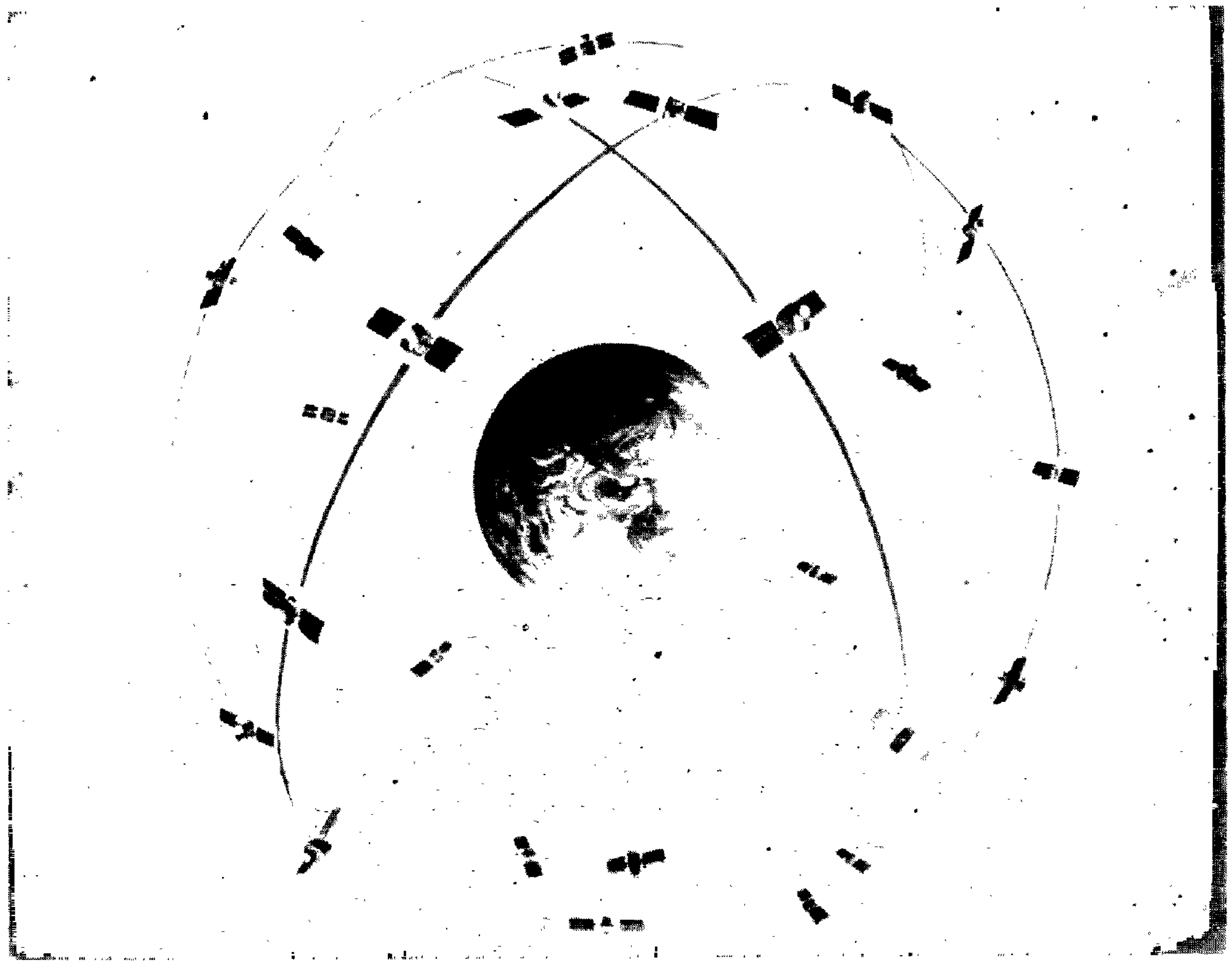
NAVSTAR PROGRAM SEQMENT INTERRELATIONSHIPS



Courtesy of U. S. Air Force

FIGURE 2

NAVSTAR SATELLITE ORBIT CONFIGURATION



Courtesy of U. S. Air Force

The user segment consists of the devices capable of receiving and processing the information received from four satellites to obtain accurate position and velocity measurements for ground, aircraft, ship, and low-orbit satellite users. The users' position and velocity are established by determining the distance from the known position of NAVSTAR satellites.

When operational, NAVSTAR is expected to consistently provide military users with position accuracies near 10 meters and velocity accuracies within 0.167 meters each second.

PROGRAM DESCRIPTION

NAVSTAR is being developed in three phases: demonstration and validation, full-scale engineering development, and production. Before entering each phase, DOD's Defense Systems Acquisition Review Council reviews the program to determine whether sufficient progress has been made to justify entering the next development phase.

The demonstration and validation phase of NAVSTAR has been completed, and the system was approved in August 1979 for full-scale engineering development. During the demonstration and validation phase, the principal objectives were to

--validate the NAVSTAR concept,

--select preferred equipment design,

--define system costs, and

--demonstrate military value.

During full-scale engineering development, new satellites, control segment, and user equipment will be designed, built, and tested to meet operational requirements. Because of the emphasis during demonstration and validation on keeping cost to a minimum, the advanced development equipment built during that phase was generally not small, efficient, or sturdy enough to meet the requirements of the operational environment. The full-scale engineering development phase will include substantial testing of the NAVSTAR system in an operational environment by the Air Force Test and Evaluation Center, the Army Operational Test and Evaluation Agency, and the Navy Operational Test and Evaluation Force.

The production phase is planned to begin in 1981 for satellites and 1983 for user equipment. Initial operational capability with 18 satellites is planned for September 1986, and the full operational satellite constellation of 24 satellites is planned for September 1987.

PROGRAM MANAGEMENT

The Air Force is the executive agency for the NAVSTAR joint service program. The Air Force Systems Command performs development testing and the Air Force Test and Evaluation Center performs operational testing of the space, control, and user segments. The Joint Program Office at the Space Division, El Segundo, California, manages the NAVSTAR program. The program manager is assisted by deputy program managers from the Air Force, Navy, Marine Corps, Army, Defense Mapping Agency, Department of Transportation, and the North Atlantic Treaty Organization.

RESULTS OF PRIOR YEAR REVIEW

In our January 1979 report (see app. I for NAVSTAR reports we issued) we expressed concern that DOD had not adequately identified total system costs, user requirements for NAVSTAR, force-effectiveness benefits from adopting NAVSTAR, navigation systems to be replaced by NAVSTAR, and cost-saving opportunities before deciding whether to enter full-scale engineering development. DOD has since performed a number of studies and analyses addressing these issues. They were considered by the Defense Systems Acquisition Review Council before making their recommendation to enter full-scale engineering development.

SCOPE

This review is part of our annual commitment to report to the Congress on selected major system acquisitions. A draft of this report was reviewed by agency officials associated with the management of the program and their comments have been incorporated in the report as appropriate.

We reviewed program documents and discussed the program at the Joint Program Office, Air Force Space Division, El Segundo, California, and obtained test information at the Army's Yuma Proving Ground, Yuma, Arizona. Discussions were held with officials in the Office of the Secretary of Defense and the military services concerning overall program planning and management.

CHAPTER 2

RESULTS OF DEMONSTRATION AND VALIDATION

The principal purpose of the demonstration and validation phase was to demonstrate that a space-based navigation system could provide highly accurate worldwide position and velocity information. Extensive testing over a 2-year period proved that NAVSTAR can provide much better data than any current system and is not degraded by various environmental conditions. Also, tests demonstrated the value of accurate navigation data to military missions such as certain weapons delivery, coordinated operations, and landing approaches.

DEMONSTRATION AND VALIDATION

During demonstration and validation, the Air Force designed and built a minimum-cost system to demonstrate the technical feasibility of NAVSTAR. As built, the system is generally capable of providing excellent navigation data to a limited geographical area for a few hours daily. To be operational, however, the system will have to be expanded considerably. Also, the demonstration and validation equipment will need redesign to meet many operational requirements not incorporated due to the minimum-cost approach.

The demonstration and validation space segment consisted of four satellites which provided periodic (up to 4 hours) coverage to selected test areas in the United States. Also, four satellites were purchased which will be used during full-scale engineering development to establish a five-satellite constellation and replenish existing satellites as they cease operation. Operational satellites will be modified versions of the demonstration and validation satellites to ensure compatability with the Space Shuttle launch vehicle and to incorporate increased survivability features.

The control segment established during demonstration and validation at Vandenberg Air Force Base, California, does not have the capability to monitor and upload a full 24-satellite constellation and, thus, is planned to be redesigned and expanded during full-scale engineering development. By 1986 an additional control station is planned to be established at Fortuna, North Dakota, which will then become the primary NAVSTAR Control Center; the Vandenberg installation will be used as an alternate.

Seven types of user equipment sets were built and tested during demonstration and validation with a variety of test vehicles. While suitable to test the concept, this equipment was not intended for operational use and, as a result, was larger and less sophisticated than planned operational sets. The operational equipment size goal for sets used in fighter aircraft is, for example, one-tenth the size of a comparable demonstration and validation set. All operational requirements will be satisfied by three types of user sets modified as necessary to meet the integration requirements of specific vehicles.

TESTING RESULTS

The program office conducted 775 test missions between March 1977 and May 1979 which successfully demonstrated the concept, design, and potential military value of the NAVSTAR system. The 22 major tests and their results are presented in appendix II. The following are highlights of some of the tests.

Position and velocity accuracies

Testing goals were exceeded by both position and velocity accuracy testing. Numerous test missions demonstrated that NAVSTAR can provide horizontal and vertical accuracies of 11 meters or better 50 percent of the time. Also, NAVSTAR measured the velocity of a test vehicle to within 0.12 meters per second. The most accurate navigation systems in operation can provide 20 to 70 meters horizontal accuracies only in limited geographical areas under the best possible conditions and cannot provide altitude or velocity measurements.

The operational NAVSTAR system is expected to provide navigation accuracies of less than 10 meters 50 percent of the time and velocity accuracies within 0.167 meters per second. Position and velocity accuracies attained during demonstration and validation testing compare favorably with the anticipated operational system requirements.

Sensitivity to jamming and environmental conditions

Limited testing was performed to demonstrate NAVSTAR's ability to resist enemy jamming of the NAVSTAR satellite signal. In general, a NAVSTAR receiver coupled with a sophisticated beam steering antenna and an inertial measurement unit successfully completed most projected missions.

However, this particular antenna system is not economically feasible for an operational system. A different type of antenna which is projected to provide similar performance but at less cost is planned for the operational system. Whether both performance and cost can be achieved remains to be demonstrated against the jamming threat. Program officials will need to stay alert to future enemy jamming of the NAVSTAR system that could degrade its performance.

The environmental conditions investigated such as propeller modulation, multipath rejection, foilage attenuation, and atmospheric conditions did not significantly affect NAVSTAR performance.

Military applications

Tests of NAVSTAR's ability to enhance certain weapons delivery, landing approaches, shipboard operations, and other applications were conducted to demonstrate NAVSTAR's potential military value. The weapons delivery tests showed that NAVSTAR could improve the accuracy of bombing as compared to current technology. This assumes accurate prior knowledge of target location. Hence, the NAVSTAR application would be more effective against fixed targets, as opposed to moving vehicles. Also, NAVSTAR allowed the use of bombing tactics which may improve military aircraft survivability and provide better night/adverse weather capability against certain targets.

Testing also demonstrated that NAVSTAR can accurately guide aircraft to a point where highly accurate precision landing approach systems take over. These tests essentially showed that NAVSTAR could replace the systems now performing this particular mission.

Using NAVSTAR, the Navy successfully guided a large vessel out of a harbor under diminished visability conditions. In a simulated man overboard test, the NAVSTAR system also enabled the ship to return precisely to where the "man" was lost.

OPERATIONAL TEST AGENCY COMMENTS

The Air Force and Navy test agencies monitored field tests conducted by the program office. The Army test agency performed its own tests. All three agencies concluded that the NAVSTAR system had demonstrated its readiness to proceed to the full-scale engineering development phase.

The Army's tests indicated that the manpack-user equipment needed several refinements to permit ease of operation in an operational environment, thereby eliminating the need for highly specialized NAVSTAR operators.

CHAPTER 3

OPERATIONAL ENVIRONMENT CONCERNS

The system designed and built during demonstration and validation generally met technical performance objectives, although many features necessary to meet demands of the operational military environment were not incorporated. However, some problems exist which, if not solved, could have serious cost, schedule, or performance implications. The emerging Soviet antisatellite capabilities will require development of programs to counter Soviet satellite systems that could threaten U.S. satellites. Accuracy of the satellite clocks tested to date has resulted in several failures, and availability of the Space Shuttle to meet the NAVSTAR schedule is uncertain.

ANTISATELLITE THREAT

Current Soviet testing of an antisatellite system could eventually result in a weapon which could threaten the survivability of our space forces. Also, the Soviets are working on other technology programs that appear to be antisatellite related. These Soviet activities could threaten our access to space, and the United States will have to continue working to defend our satellites. These Soviet threats could affect the NAVSTAR program.

SATELLITE RELIABILITY QUESTIONABLE

The cost of the NAVSTAR system is based upon the satellites providing accurate information for 6 years each. If the satellites do not attain this goal, they will have to be replaced, thus increasing system costs. The satellites launched during demonstration and validation generally operated satisfactorily with the exception of their self-contained atomic clocks, which must work well for users to obtain reliable, accurate navigation information. The clocks met accuracy requirements during demonstration and validation but experienced reliability problems. A satellite is essentially useless to users if the clocks are not working properly.

Also, the operational NAVSTAR system is supposed to provide users with good information for at least 2 weeks if for some reason the NAVSTAR control center cannot update the satellites. This survivability objective may not be assured if the clock problems are not solved.

Each of the four satellites launched contained three rubidium atomic clocks. The fourth satellite also had an experimental cesium atomic clock. The satellites have multiple clocks to provide a replacement capability if one fails. Each clock also has a backup mode which could take over if the primary mode fails. However, the backup mode is accurate for only a short period of time and cannot provide the required accuracy in an operational environment without frequent corrections by the NAVSTAR control center.

The following table shows the results of tests performed on atomic clocks.

Results of Testing
of NAVSTAR Satellite Clocks
October 31, 1979

Satellite	Clocks I	Clocks II	Clocks III	Clocks IV
1	a/Failed	b/Abnormal	a/Failed	-
2	c,d/Failed	a/Failed	Abnormal	-
3	No problems	Abnormal	Untried	-
4	Untried	No problems	Untried	e/Failed

Cause of failure: a/rubidium lamp, b/resulted in circuit modification on subsequent clocks, c/transformer, d/resulted in tranformer modification on subsequent clocks, and e/power supply.

As indicated above, eight of the clocks either failed or acted abnormally. If clock reliability cannot be improved significantly during full-scale engineering development (1) the satellites may have to be modified to accommodate additional backup clocks or (2) additional satellites may be required to maintain an operational constellation. Either change could cost millions of dollars.

The clock failures

The clock failures have been traced to malfunctions of three components: the transformer, power supply, and rubidium lamp. The first clock failure occurred on the second satellite launched (NAVSTAR-2) and was caused by a transformer malfunction. The clocks in NAVSTAR-3 and -4 were modified before their launch to prevent reoccurrance of this problem.

The experimental cesium clock on NAVSTAR 4 failed due to a power supply malfunction after operating 11 hours. This clock had not been subjected to the exhaustive reliability testing normally applied to satellite components. Program officials explained that the clock was launched as an experiment to obtain early on orbit performance data. The cesium clock is being evaluated as a possible replacement for rubidium clocks because it is inherently more stable. Cesium clocks placed on future NAVSTAR satellites will be preproduction models which have met high reliability standards.

The most serious problem has been the rubidium lamp malfunctions which have caused three clocks to fail. The contractor determined that the malfunction was caused by an unexpected chemical reaction; the rubidium in the lamp was reacting with a minute contaminant, thus using up the rubidium essential to the clock's proper operation. Future rubidium clocks will incorporate several changes which contractor and program office personnel believe will eliminate this problem. However, the nature of the problem is such that the solution cannot be confirmed until the clock has operated successfully in space.

The abnormal clocks

In addition to the clock failures, several clocks have acted abnormally for short periods of time which diminishes the accuracy of the information received by the user. The clock abnormalities are often correctable by control center intervention. However, the corrections can only be made when the satellite is in view of the control center--about every 12 hours.

SPACE SHUTTLE AVAILABILITY

The program office has been directed to use the Space Shuttle to place an estimated 76 NAVSTAR satellites into orbit through the year 2000. However, the Space Shuttle program has encountered problems which could delay its availability for launching the first NAVSTAR operational satellites beginning in 1983. This could jeopardize DOD's plan to have the NAVSTAR system fully operational by September 1987.

The program office does not know whether the Space Shuttle problems will definitely affect the NAVSTAR program. As a contingency, however, the program office is studying the use of Titan or Atlas boosters to launch the first operational satellites if the Space Shuttle is not available.

The program office estimated that this could cost an additional $12 million to $38 million for each satellite launched as compared to currently projected Space Shuttle launch costs.

CONCLUSIONS

To date, NAVSTAR has generally met technical performance objectives, although some problems still exist which, if not solved, could have substantial implications.

For example, current Soviet testing of an antisatellite system could eventually result in a weapon which could threaten the survivability of our forces. DOD should closely monitor this emerging Soviet threat and continue to assess its impact in developing and planning the NAVSTAR system.

Satellite clock reliability has not been demonstrated in space. The satellite clocks must work well for users to obtain reliable and accurate navigation information. If the problems which caused eight of the clocks to either fail or operate abnormally are not solved, alternate solutions could cost millions of dollars.

Space Shuttle problems could also jeopardize DOD's plan to have NAVSTAR fully operational by 1987. The use of Titan or Atlas boosters in place of the Space Shuttle to meet NAVSTAR launch requirements could cost an additional $12 million to $38 million for each satellite launched.

CHAPTER 4

NAVSTAR COSTS, BENEFITS, AND SCHEDULE

In our January 17, 1979, report we identified several issues concerning the total cost of acquiring the NAVSTAR capabilities and the resulting benefits. Since then, DOD has completed a number of analyses which address these issues. The current estimate to acquire and support NAVSTAR is significantly greater than previously estimated due primarily to the inclusion of life-cycle costs through the year 2000. However, we believe that studies have identified many potential benefits that will improve the operations of U.S. forces. (See pp. 29 and 30.)

Since the program was initiated in December 1973, the original full operational capability date of August 1985 has slipped 25 months. Twelve months of this delay occurred in the last year. This was due to (1) a delay in beginning operational satellite design and (2) an Air Force decision to slip production funds from the fiscal year 1981 budget to fiscal year 1982 because of higher priorities. More detailed schedule information is presented in appendix III.

COST ESTIMATES

In previous estimates, DOD nad not included the cost of the following items which we believed were integral parts of the NAVSTAR system:

--Procurement, integration, operation, and support costs of the receivers purchased by the military services.

--The cost of replenishment satellites necessary to maintain the system beyond the initial operating capability.

--The Space Shuttle launch costs to place the operational satellites into orbit.

For the May 1979 Defense Systems Acquisition Review Council review, the program office estimated that DOD's costs to acquire and maintain NAVSTAR through the year 2000, including these items, would exceed $8.6 billion.

The following table shows the cost changes since the program began in December 1973.

NAVSTAR Cost Estimates

Development phase	Program estimates Dec. 1973	Feb. 1978	May 1979	Increase (decrease) from 1978 to 1979
	(millions in then-year dollars)			
Demonstration and validation	$177.9	$ 406.3	$ 364.9	$ (41.4)
Full-scale engineering development	253.4	679.6	839.7	160.1
Production	383.1	659.1	7,445.4	6,786.3
Total	a/$814.4	a/$1,745.0	b/$8,650.0	$6,905.0

a/These estimates do not include any costs necessary to operate NAVSTAR beyond initial operational capability such as user equipment procurement costs, Space Shuttle launch costs, or replenishment satellites. Also, the program envisioned in the December 1973 estimate underwent substantial restructuring in 1977.

b/This value extends the February 1978 estimate to include DOD's costs to acquire and maintain NAVSTAR through the year 2000, including such items as Space Shuttle launch costs, user equipment procurement, and 40 replenishment satellites.

The production phase costs increased from $659.1 million to $7,445.4 million and reflects the largest portion of the increase. This increase is made up of the following costs.

Cost element	Program office estimate Feb. 1978	May 1979
	(millions in then-year dollars)	
Satellite	$584.7	$2,686.0
Launch vehicle	-	1,707.2
Control	59.8	85.1
Military construction	3.0	6.0
User integration	11.6	a/1,875.0
Operation and support	-	587.0
Service unique support equipment/integration:		
Army	-	170.0
Navy	-	321.1
Defense Mapping Agency	-	8.0
Total	$659.1	$7,445.4

a/The May 1979 estimate is based on costs of production user equipment including spares and Army Reserve forces--a total of 19,261 sets. The military departments, as discussed on page 16, have committed to buy only 14,828 sets, which does not include spares or Army Reserve forces.

More detailed program cost information is presented in appendix IV.

DOD plans to phaseout use of several navigation systems

As NAVSTAR is implemented, DOD plans to phaseout or reduce its use of several current navigation systems.

The table below shows the systems which DOD plans to phaseout or reduce its use, the phasing time period, and their associated costs.

DOD Phaseout Plan

System	DOD use--phased out or reduced	Phasing time period FY 1986 thru	Associated costs
			(millions in then-year dollars)
Tacan	Reduced	1995	$ 478 to 1,093
Loran	Reduced	1992	230 to 355
Omega	Reduced	1992	148 to 255
Transit	Out	1992	124 to 247
Vor-Dme	Out	1995	139 to 157
Raydist	Out	1995	11 to 12
Total			$1,130 to 2,119

The Air Force study also indicates that NAVSTAR could potentially replace or reduce the use of the Automated Distance Finding System, marker beacons, and Doppler Navigation/velocity equipment. DOD's cost to continue use of these systems through the year 2000 were estimated to be from $.9 billion to $1.2 billion.

USER REQUIREMENTS AND COMMITMENTS

In our January 1979 report we commented that the development of NAVSTAR was not started to satisfy unmet military needs or operational deficiencies but rather to generally improve navigation capabilities. Despite the lack of specific user needs, DOD had estimated there were 27,000 military users who would need NAVSTAR capabilities.

Since then, the Air Force, Army, and Navy have defined specific mission requirements for improved navigation accuracies which are not met by any current navigation system or combination of systems. With few exceptions, these requirements will be satisfied by NAVSTAR.

The military departments plus the Defense Mapping Agency are generally committed to buy at least 14,828 NAVSTAR receivers over a 16-year period beginning in 1984, as follows:

Air Force	11,732
Army	1,616
Navy	1,430
Defense Mapping Agency	50
Total	14,828

Program officials stated that the services' commitments may change up or down depending on further analyses, defense appropriations, or priority changes. Program officials expect the demand to increase as the services become more knowledgeable and confident of the force-effectiveness benefits offered by NAVSTAR.

The following sections discuss the commitments each military department made to NAVSTAR.

Air Force

The Air Force anticipates NAVSTAR receiver installations on virtually all its manned aircraft. Installation priorities are given to weapons delivery and reconnaissance aircraft. To avoid disruption of normal operations, the NAVSTAR equipment will generally be installed as the aircraft receive its normal major maintenance.

Army

The Army has established a high- and low-mix concept for NAVSTAR receivers, depending upon whether it acquires the Position Location Reporting System which is under development. This system can satisfy the Army's position accuracy requirements for some missions and has the added advantage of a reporting feature which facilitates command and control.

If the Position Location Reporting System is not acquired, the Army projects a need for 13,217 NAVSTAR sets. However, the Army is assuming that the system will be acquired and plans to buy only 1,616 NAVSTAR sets. Army officials do not expect their NAVSTAR receiver needs to increase significantly in the future if the Position Location Reporting System is acquired.

Navy

The Navy has postulated a potential need for 4,742 NAVSTAR receivers based on known and potential navigation accuracy requirements. It is committed, however, to purchasing only 1,430 receivers for ships, submarines, aircraft, and land users which definitely need NAVSTAR to satisfy their accuracy or availability requirements. Additional sets may be required as new requirements emerge or as current navigation systems such as VORTAC and Vor-Dme are phased out.

BENEFITS OF NAVSTAR IMPLEMENTATION

Because the cost of NAVSTAR far exceeds expected savings from reducing DOD's use of other systems, the justification for implementing NAVSTAR depends heavily on the benefits provided by its increased navigational accuracy, global coverage, and other characteristics. Numerous DOD studies indicate that NAVSTAR should improve the effectiveness of military missions.

The majority of the force-effectiveness studies dealt principally with weapons delivery and related missions because of the relative ease in quantifying the results. The weapons delivery mission is DOD's principal requirement for improved navigation capabilities.

Using NAVSTAR, the studies demonstrated that a given target can be destroyed by employing fewer resources (for example, bombs, planes, warheads, and so forth) than with current navigation systems. A specified force such as an aircraft squadron or artillery unit can destroy more fixed targets than a similar force not equipped with NAVSTAR. The following is one of several examples cited by The Analytic Sciences Corporation in its cost-benefit analysis study of the NAVSTAR system which illustrates the potential significance of employing NAVSTAR.

--An interdiction force of 1,465 aircraft could achieve a target kill rate equivalent to that of 1,714 aircraft not equipped with NAVSTAR. According to this study, the cost of the additional 249 aircraft (for example, F-4s, F-16s, and F-18s) needed to achieve the same target kills as the NAVSTAR-equipped force would exceed $7 billion.

This study of other weapons' delivery missions reached essentially the same conclusion--a NAVSTAR-equipped force is significantly more effective in locating and destroying fixed targets than a similar-sized force equipped with current navigation aids.

In our January 17, 1979, report DOD officials acknowledged that a comprehensive study was needed which identified and summarized the force-effectiveness benefits expected from using NAVSTAR. Such a study has been completed. We reviewed this study, and it shows that certain weapons delivery missions could possibly demonstrate cost benefits by implementing NAVSTAR.

In addition to weapons delivery missions, other studies have demonstrated the value of NAVSTAR to such missions as enroute navigation, search and rescue, and mine sweeping. For example, a study by the Army's Training and Doctrine Command indicated that medical evacuation of wounded soldiers could be accomplished quicker and with less risk to helicopters if NAVSTAR were in use.

CONCLUSIONS

Acquiring and maintaining the NAVSTAR system through the year 2000 will cost an estimated $8.6 billion. This cost includes several items which had not been included in previous estimates such as user equipment procurement, cost of replenishment satellites, and Space Shuttle launch costs.

The Army, Navy, Air Force, and Defense Mapping Agency have committed to buy 14,828 NAVSTAR receivers over a 16-year period beginning in 1984. Their commitments may change, however, depending on further analyses, defense appropriations, or priority changes.

We believe that force-effectiveness studies have demonstrated that NAVSTAR could improve the effectiveness of some military missions. A NAVSTAR-equipped force could possibly be more effective in delivering weapons than a similar-sized force equipped with current navigation aids.

OUR PRIOR REPORTS REGARDING NAVSTAR

1. "Comparison of the Navstar Program With the Acquisition Plan Recommended by the Commission on Government Procurement," (PSAD-77-50, Jan. 24, 1977).

2. "Status of the Navstar Global Positioning System," (PSAD-77-23, Mar. 2, 1977).

3. "Navigation Planning--Need For A New Direction," (LCD-77-109, Mar. 21, 1978).

   Navigation systems have proliferated, adding to Government and user costs. The Department of Defense's navigation satellite system, NAVSTAR, offers the potential to replace numerous other systems at substantial savings.

   Better planning and management is needed if its benefits as a national resource are to be realized and strong management at the executive level of the President is necessary to overcome agency parochialism and carry out a Government-wide navigation plan.

4. "Status of the Navstar Global Positioning System," (PSAD-78-37, Apr. 25, 1978).

   The Air Force is developing the NAVSTAR Global Positioning System for precise worldwide positioning or navigation. It will be used by the Air Force, Navy, and Army and possibly by military allies and civilians. Developmental problems have delayed the program about 1 year. The system will be tested from July 1978 through February 1979.

5. "The Navstar Global Positioning System--A Program With Many Uncertainties," (PSAD-79-16, Jan. 17, 1979).

   The Air Force is developing the NAVSTAR Global Positioning System for precise worldwide position and navigation capability. The current Defense Department program cost estimate is $1.7 billion in related systems costs and an undetermined amount for escalation costs.

   Defense is studying user needs, force effectiveness, replacement plans, and cost savings opportunities to decide on whether to approve the program for full-scale engineering development. GAO is concerned about the completeness and depth of coverage of the studies in view of the limited time remaining before the scheduled May 1979 review and subsequent decision by the Secretary of Defense.

6. "Should Navstar Be Used for Civil Navigation? FAA Should Improve Its Efforts To Decide," (LCD-79-104, Apr. 30, 1979).

The Federal Aviation Administration is evaluating DOD's planned NAVSTAR satellite navigation system to determine if it should also become the primary civil air navigation system.

Before a decision is made, assurance is needed that DOD will develop, test, and deploy NAVSTAR and allow the civil community full access to its signals under all conditions other than national emergency.

This report discusses the evaluation program and the work FAA has done or plans to do as of this time and concludes that FAA should improve its NAVSTAR evaluation program if its benefits to civil aviation are to be considered.

DEMONSTRATION AND VALIDATION

TEST AND RESULTS

Field tests	Field test results
1. Position accuracy	11.1 meters, 50% probability 22.0 meters, 90% probability All sets, 3 dimensions
2. Velocity accuracy	.12 to .8 meters per second
3. Effects of vehicle dynamics on accuracy	90% probability that accuracy will not be degraded more than 2.5 meters
4. Precision weapon delivery	Performance demonstrated, result classified
5. Landing approach	Consistently within instrument landing system beacon limits down to 200 feet
6. Rendezvous	Within 29 meters for air-to-air, and air/sea rendezvous
7. Photomapping	Successfully demonstrated target location capability within 7.4 meters
8. Nap of Earth operations	No accuracy degradation
9. Static positioning	Provides static users an 8.15 meter (real time) position with 68% probability
10. Combined operations	Demonstrated common grid air/troop/ground vehicle operations
11. Cross country	An aircraft navigated from Hawaii to California with NAVSTAR as the primary means of navigation
12. Shipboard operations	A ship navigated San Diego channel in low visibility on NAVSTAR to within 32.2 meters of channel buoys

Field tests	Field test results
13. Jam resistance	Performance demonstrated, result classified
14. Selective availability	Performance demonstrated, result classified
15. Propeller and motor modulation	No effect on navigation accuracies
16. Foliage attenuation	Demonstrated navigation through dense and light foliage
17. Multipath rejection	Minor error in navigation accuracy
18. Ionospheric and tropospheric correction	Effective error eliminated within 2 meters, 68% probability
19. Satellite clock and ephermeris accuracy	5.5 meters 2 hours after update, 68% probability 11.5 meters 24 hours after update, 68% probability
20. Acquisition and reacquisition time	Cold start 15 minutes or less Warm start 5 minutes or less, reacquisition .5 to 28 seconds
21. Time transfer	Time transferred with an accuracy of ± 25 nanoseconds with 68% probability
22. Signal levels and structure	No problems with either the signal level or the signal structure

COMPARISON OF OCTOBER 1978 AND OCTOBER 1979 SCHEDULES

Phase	Last year's schedule (Oct. 1978)	Current schedule (Oct. 1979)	Delay (months)
Validation:			
Approval	a/Dec. 1973	-	-
Acquisition Council's review for beginning full-scale engineering development	May 1979	a/May 1979	-
Full-scale engineering development:			
User equipment four-contractor competition to start	a/Mar. 1978	a/Mar. 1978	-
User equipment final contracts awards (two contractors)	June 1979	a/Aug. 1979	2
Begin initial field testing of user equipment	Nov. 1981	Mar. 1982	4
Begin operational master control and upload station operations	Apr. 1983	Nov. 1983	7
Acquisition Council's review for beginning production:			
User equipment	Apr. 1983	Sept. 1983	5
Satellites	Mar. 1981	Oct. 1981	6
Production:			
Begin operational testing of user equipment	Oct. 1984	Mar. 1985	5
Initial operational capability (18 satellites)	Sept. 1985	Sept. 1986	12
Full 24-satellite operation	Sept. 1986	Sept. 1987	12

a/Actual occurrence.

CHANGES IN COST ESTIMATES

(Demonstration and Validation)

Cost element	Program office estimate: Estimate (Dec. 1973)	Estimate (Feb. 1978)	Actual (May 1979)	Increase (decrease) from Feb. 1978 to May 1979
	----------(millions in then-year dollars)----------			
Spacecraft support	$ 85.3	$171.9	$103.0	$(68.9)
Launch vehicles	28.1	52.7	47.5	(5.2)
Control/user equipment	47.9	138.0	158.7	20.7
Testing	11.3	11.8	27.8	16.0
Technical support	5.3	28.4	27.9	(.5)
1977 escalation index changes	-	3.5	-	(3.5)
Total	$177.9	$406.3	$364.9	$(41.4)

(Full-Scale Engineering Development)

Cost element	Program office estimate: Dec. 1973	Feb. 1978	May 1979	Increase from Feb. 1978 to May 1979
	---------(millions in then-year dollars)-----------			
Satellite	$126.2	$216.8	$218.1	$ 1.3
Launch vehicle	44.3	32.3	36.9	4.6
Control	19.7	91.4	141.3	49.9
User equipment/ testing	55.4	203.1	205.2	2.1
Technical support/ other	7.8	-	-	-
Military construction	-	36.0	53.5	17.5
Service-unique user:				
Navy	-	45.2	108.3	63.1
Army	-	54.8	76.4	21.6
Total	$253.4	$679.6	$839.7	$160.1

(Production Phase)

Cost element	Program office estimate Dec. 1973	Feb. 1978	May 1979	Increase from Feb. 1978 to May 1979
	-----------(millions in then-year dollars)---------			
Satellite	$219.2	$584.[illegible]	$2,686.0	$2,101.3
Launch vehicle	110.6		1,707.2	1,707.2
Control	23.6	59.8	85.1	25.3
Testing	23.5		-	-
Technical support	6.2		-	-
Military construction	-	[illegible]	6.0	3.0
User integration	-	[illegible]	a/1,875.0	1,863.4
Operation and support	-		587.0	587.0
Service-unique user equipment/integration:				
Army	-		170.0	170.0
Navy	-		321.1	321.1
Defense Mapping Agency			8.0	8.0
Total	$383.1	$659.1	$7,445.4	$6,786.3

a/The May 1979 estimate is based on costs of production user equipment including spares and Army Reserve forces--a total of 19,261 sets. The military departments, as discussed on page 16, have committed to buy only 14,828 sets which does not include spares or Army Reserve forces.

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