BY THE COMPTROLLER GENERAL

8886

Report To The Congress

OF THE UNITED STATES

The NAVSTAR Global Positioning System--A Program with Many Uncertainties

The Air Force is developing the NAVSTAR Global Positioning System for precise worldwide position and navigation capability. The current Department of Defense program cost estimate is $1.7 billion. However, this estimate does not include more than $2.5 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 in preparation for a decision 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.

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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 of the NAVSTAR Global Positioning System. 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 weapon systems. This report is one of a series that is being furnished to the Congress for its use in reviewing fiscal year 1980 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 Director, Office of Management and Budget, and the Secretary of Defense.

Comptroller General
of the United States

COMPTROLLER GENERAL'S REPORT TO THE CONGRESS

THE NAVSTAR GLOBAL POSITIONING SYSTEM--A PROGRAM WITH COST AND BENEFIT UNCERTAINTIES

D I G E S T

The NAVSTAR Global Positioning System is a space-based navigation system designed to provide users with worldwide three-dimensional position and navigation information. Almost all military aircraft, surface ships, and submarines are potential users of the system, as are some land vehicles and ground troops. Military allies and civilians could also use it. (See p. 2.)

The system will consist of 24 satellites, ground control equipment, and user equipment. Four of the satellites have already been launched. (See pp. 2 and 16.)

The Department of Defense's justification for the program was to

--consolidate navigation satellite research programs,

--improve weapon system effectiveness by increasing navigation accuracy and global coverage, and

--promote potential cost savings. (See p. 6.)

The program is currently in the validation phase and the next major Department of Defense program review is scheduled for May 1979. This review by the Defense System Acquisition Review Council, is to determine if the program should enter full-scale engineering development. The fully operational capability is programed for 1986. (See p. 18.)

The most current program cost estimate for the Global Positioning System is $1.7 billion. However, this estimate does not include over $2.5 billion estimated by Defense for the costs of user equipment, replenishment satellites and Space Shuttle launch costs. In addition, an undetermined amount for escalation

costs is not included in this $2.5 billion estimate. Consequently, the estimated total program cost is in excess of $4.25 billion. (See p. 13.)

The cost savings and force effectiveness improvements anticipated if the Global Positioning System is deployed have not been fully defined. Although studies concerning the potential for force effectiveness have been and are being made, the accuracy, coverage and other characteristics required for individual users to significantly improve the effectiveness of their weapon systems have not been identified and summarized as a cohesive justification for the Global Positioning System. (See p. 7.)

Potential cost savings from the Global Positioning System have not been identified. To estimate potential savings, the following studies need to be completed:

--Phaseout study identifying specific systems to be replaced and the costs avoided by replacing these systems. (See p. 8.)

--Complete life-cycle cost study including all user and support costs. (See p. 8.)

--Although Defense has consistently emphasized the need for developing valid user information, the 27,000 potential users estimated by Defense have been slow in committing themselves to the system. (See p. 9.)

Available validation phase test results, although based on limited testing, are very promising and Defense believes the degree of accuracy envisioned with the Global Positioning System will probably be obtained. Testing has been affected by delays in obtaining the number of satellites required for meeting the test objectives. Despite these delays, program officials plan to have four satellite test data available for the upcoming May 1979 review. (See p. 16.)

Defense is currently studying user needs, force effectiveness, replacement plans, and cost savings opportunities in preparation for the May 1979 review. In view of the limited time remaining before the review and the significant amount of effort that has to be done, GAO is concerned about the completeness and depth of coverage of these Defense-wide studies. Defense officials are confident that all needed information will be available in time for this review.

The Secretary of Defense should determine that the following information has been adequately developed and analyzed before deciding on whether to proceed into full-scale engineering development. Specifically:

--The individual military users are identified and these users make specific commitments on how they will use the system.

--Force effectiveness benefits cited in any justification for acquiring the Global Positioning System are supported by a well defined need or significant savings.

--Any cost savings attributed to replacing existing navigation systems are supported by specific commitments and plans for the phaseout of these systems.

--All related system costs are computed and incorporated in the total estimated cost of the program.

The Congress should require the Secretary of Defense to identify the individual weapon systems that will use the Global Positioning System before it approves fiscal year 1980 full-scale engineering development funds. For each of these users, the Secretary should identify

--what required force effectiveness improvements will result,

--what commitments have been made by the Services to eliminate alternative navigation systems, and

--what net potential cost savings have been identified after all life-cycle costs have been considered.

This report was reviewed by agency officials associated with the management of the program. Their comments have been incorporated in the report as appropriate.

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ABBREVIATIONS

DOD	Department of Defense
DSARC	Defense System Acquisition Review Council
GAO	General Accounting Office
GPS	Global Positioning System
JCS	Joint Chiefs of Staff

CHAPTER 1

INTRODUCTION

The NAVSTAR Global Positioning System (GPS) is a Department of Defense (DOD) program intended to meet the future Armed Forces position and navigation requirements.

Since the early 1960s the Navy and the Air Force have pursued the development of navigation and position location systems using radio signals transmitted from space vehicles. Both services conducted programs to demonstrate the feasibility of navigation satellite systems. The Navy has sponsored two programs (1) TRANSIT, operational since 1963, and (2) TIMATION, a technology program to improve, among other things, two-dimensional navigation (i.e., longitude and latitude). The Air Force concurrently conducted preliminary studies for a three-dimensional (longitude, latitude, and altitude) navigation system called System 621B.

In 1967 the Joint Chiefs of Staff (JCS) conducted a comprehensive study of all navigation systems in operation or advanced development. The purpose of that study was to ascertain the most cost effective combination of systems that would meet military requirements for position fixing. The study, which resulted in the JCS Master Navigation Plan, concluded among other things that:

--No system or combination of systems existed at that time that could meet all the essential requirements.

--A space-based navigation system would be most likely to fulfill established navigation requirements, and should be given priority to attain operational status as soon as possible.

Navy and Air Force efforts to achieve higher precision satellite navigation were combined in April 1973 at the direction of the Deputy Secretary of Defense. The Air Force, designated the executive service for the joint program, was directed to prepare plans for a comprehensive system based on the former Navy and Air Force programs. The GPS concept was presented to the Defense System Acquisition Review Council (DSARC) and in December 1973, the Deputy Secretary of Defense, following the DSARC recommendation, approved initiating the program. The program is currently in the validation phase and the next major DSARC review (DSARC II) is scheduled for May 1979. This review is to determine if the program should enter full-scale development. The fully operational capability is programed for 1986.

SYSTEM DESCRIPTION

GPS is a space-based radio navigation system designed to provide users with worldwide three-dimensional position and navigation information. Potential military users include almost all aircraft, surface ships, submarines, as well as some land vehicles and ground troops. GPS could be used to enhance such missions as all-weather weapons delivery, reconnaissance, mapping and rendezvous. Additionally, GPS may replace many existing navigation aids presently needed for routine point-to-point navigation.

DOD currently projects over 27,000 GPS users. Civilian and North Atlantic Treaty Organization use of GPS is also projected. In the case of civilian users, DOD is considering the need to deny or otherwise degrade the system accuracy and the conditions under which the denial and degradation would be imposed.

The GPS concept includes three major segments:

--A space segment consisting of 24 satellites which will broadcast position coordinates and timing information to users.

--A control segment to track the satellites and update position coordinates and timing information daily. It will include four or more monitor stations to track satellites, a master control station to determine signal accuracy, and an upload station to relay data to the satellites.

--A user segment consisting of devices to receive and process information from four satellites to obtain accurate position and velocity components for the ground, aircraft, and ship users. The user's position and velocity are established by determining the distance from the known position of GPS satellites.

Figure 1 shows the interrelationship of these segments in a typical operational environment.

PROGRAM DESCRIPTION

The GPS program is being managed in three phases: concept validation (phase I), full-scale engineering development (phase II), and production (phase III). DSARC reviewed the program at the beginning of the validation phase, and will review the program at the beginning of each of the remaining

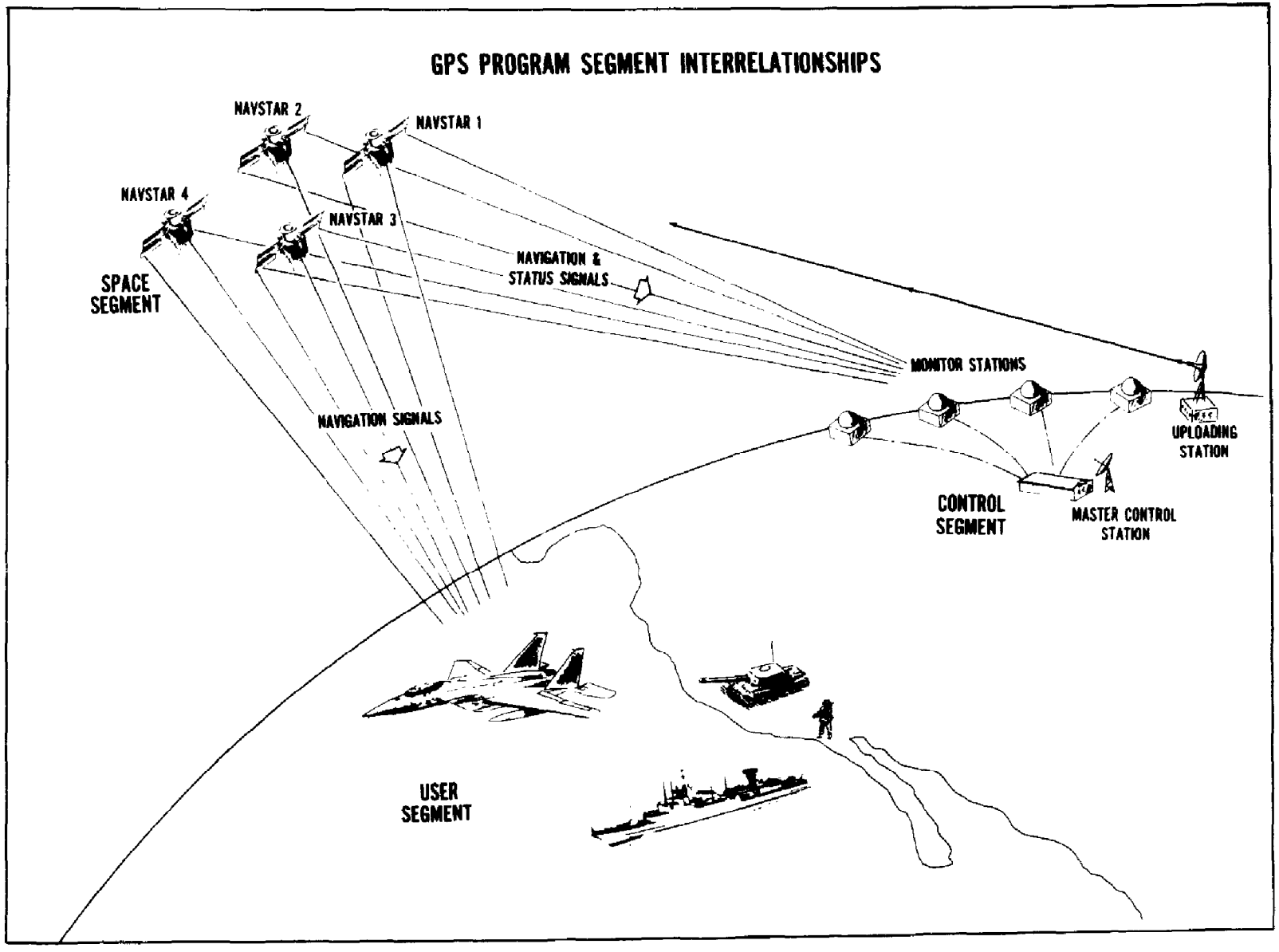
GPS PROGRAM SEGMENT INTERRELATIONSHIPS
NAVSTAR 2
NAVSTAR 1
NAVSTAR 4
NAVSTAR 3
SPACE SEGMENT
NAVIGATION & STATUS SIGNALS
MONITOR STATIONS
NAVIGATION SIGNALS
UPLOADING STATION
CONTROL SEGMENT
MASTER CONTROL STATION
USER SEGMENT

FIGURE 1.

phases to determine whether sufficient progress has been made to warrant recommending to the Secretary of Defense whether the program should be advanced into the next phase. Summary information on these phases follows.

Concept validation phase

Start: December 1973

Expected completion: May 1979

Key activities in this phase are to identify user equipment types (see app. I) and potential users, plan performance capability, launch satellites for testing, test user equipment performance capability, and develop a prototype control station.

Full-scale engineering development phase

Expected start: May 1979

Expected completion: 1983

This phase will involve (1) development, fabrication, and initial production of operational satellites to augment satellites launched in phase I; (2) major development of the control segment, including the installation of a survivable, autonomous master control station in the continental United States; and (3) extensive development and initial operational test and evaluation of user equipment.

Production phase

Expected start:

1981 (Satellite and control segment production)
1983 (User equipment production)

Initial operating capability (18 satellites): 1985
Full operating capability (24 satellites): 1986
Installation on user vehicles: 1985 to 1990's

This phase will involve deploying the complete operational satellite constellation, upgrading and operating a backup master control station, and producing and installing all classes of user equipment.

PRIOR GAO REVIEWS

This is the third report on the GPS program. In our previous reports we recommended that the requirements for the system be validated, that the total cost be estimated, and that the program be placed in the Selected Acquisition Reporting system. Although DOD agreed with our previous recommendations, it has not completed these actions. In commenting on our draft report, DOD officials said these actions will be completed in conjunction with DSARC II.

SCOPE

This review is part of our annual commitment to report to the Congress on selected major weapon system acquisitions. This report should aid the Congress when considering DOD's fiscal year 1980 budget request.

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

CHAPTER 2

INCREASED FORCE EFFECTIVENESS AND COST SAVINGS ARE UNKNOWN

The GPS program originated as a result of the JCS study conducted in 1967 (see ch. 1). This study concluded that unmet navigational requirements existed and that a space-based system would be the most likely way to fulfill established requirements. As a result, the GPS program emerged in 1973 as an effort to consolidate navigation satellite research programs and to improve weapon system effectiveness by increasing navigational accuracy and global coverage. In addition, the GPS program was to promote cost savings by eliminating some navigational systems and stopping the proliferation of new ones.

During our review, we noted that the requirements referred to in the 1967 study were related to the capabilities of navigation systems in general, rather than to unmet needs or identified deficiencies of specific individual military users. Because of this, much uncertainty currently exists concerning who the individual users will be and what their specific needs are for the capabilities to be offered by the GPS program. Consequently, the value of improved weapon system effectiveness and cost savings compared to the cost of the program have not been demonstrated because:

--A comprehensive force effectiveness analysis identifying the value of GPS to individual users has not been completed.

--An analysis has not been completed that defines the extent of the replacement of some existing navigation systems and the stopping of the proliferation of new systems, and identifies the associated cost savings if the GPS is acquired.

DOD plans a major program review--DSARC II--in May 1979 to consider whether GPS should enter full-scale engineering development. We are concerned that unless the uncertainties pertaining to improved force effectiveness and potential cost savings are resolved, the soundness of the pending decision to proceed with GPS development could be jeopardized. As of December 1978, the Secretary of Defense did not have this data and much additional work remains to be done before the DSARC II review in May 1979.

DOD HAS NOT DEMONSTRATED THE BENEFITS OF GPS

In 1978, the Under Secretary of Defense for Research and Engineering, testifying about the need for GPS, told the Senate Commerce, Science, and Transportation Subcommittee:

> "If NAVSTAR provides the expected capability we can make a major reduction in the use of other, more specialized navigation systems."
>
> "A fully implemented program could achieve a net cost savings for military users of over $200 million per year."
>
> "Our analyses show that we can greatly reduce costs and improve force effectiveness by the earliest employment of the system."

These statements were also made in 1977 hearings. DOD was unable, however, to provide documents as evidence for either their 1977 or 1978 Senate testimony.

We recognize that no single mission should be expected to justify the cost of deploying the GPS. It is the combined effect on all potential mission scenarios, plus the benefit of a common, global system for all U.S. and allied forces that must be considered. At the time of our review, DOD had not completed an analysis that considered the GPS in this way. In addition, phaseout or GPS life-cycle cost studies had not been completed to determine if any savings could result if GPS replaces other navigation systems.

DOD-wide force effectiveness benefits have not been determined

The justification for GPS depends heavily on the increased force effectiveness anticipated as a result of improved navigational accuracy, global coverage, and other essential characteristics. Although studies concerning the potential for force effectiveness have been and are being made, the performance characteristics required by individual users to significantly improve the effectiveness of their weapon systems have not been identified and summarized as a cohesive justification for the GPS program.

Because the GPS represents improvements over the capabilities of existing navigational systems, the application of this improved technology would appear to be beneficial to almost all DOD missions requiring precise positioning and

navigation data. The studies that have been funded have generally shown that this potential exists in varying degrees for a large number of missions. Furthermore, according to agency officials, testing during the validation phase has shown that the degree of accuracy envisioned with GPS will probably be obtained.

Although we do not question the orginal basis for the program or the work that has been done during the validation phase, we believe that because the program is rapidly approaching the decision to enter full-scale engineering development, more specifics are required. These concern the need for improved accuracy and greater coverage (over current capabilities) for each type of weapon system that utilizes positioning and navigation data. As a result of our reviewing many study reports and our discussions with DOD officials, we found that these specifics do not exist.

In commenting on our draft report, agency officials agreed that this information is vitally needed and that it will be available in time for the DSARC II review. They acknowledged that a comprehensive benefit study is needed to identify and summarize all expected force effectiveness benefits. A contract was awarded in December 1978 to conduct such a study. In our opinion, this analysis is crucial for determining if a sufficient need exists that would offset the cost of this multibillion dollar program. DOD officials said the results of this contract will be available in time for the DSARC II review.

Potential cost savings have not been quantified

The most definitive statement DOD made on potential cost savings is that "* * * a fully implemented GPS program could achieve a net cost savings for military users of over $200 million per year." However, as stated earlier, DOD has not provided any support for this statement. Program officials stated that such support cannot be obtained until the following studies are completed

- --phaseout study identifying specific systems which will be replaced by GPS and the costs avoided by replacing these systems, and

- --complete GPS life-cycle cost study including all user and support costs.

In commenting on our draft report, DOD officials stated that a phaseout study is in progress with initial results

to be available by mid-February 1979. In addition, they stated that a life-cycle cost study is to be completed by March 1979 in support of the DSARC II review.

With respect to the phasing out of existing systems, we noted that the 1973 program justification identified a number of systems that could be replaced by GPS. These were (1) TACAN, (2) LORAN, (3) TRANSIT, and (4) OMEGA.

The Navy plans, however, to continue to use OMEGA and LORAN. Additionally, despite the prospect of GPS becoming operational in 1985, improvements are being funded for all four of the above systems. For example, almost all Navy and Air Force aircraft are expected to be retrofitted with an improved TACAN navigation system between 1977 and 1981. If GPS is acquired, GPS units could be installed on these aircraft as additional navigational equipment beginning in 1985. In commenting on our draft report, DOD officials stated that the TACAN retrofit referred to above is cost effective because the new TACAN units are more reliable, resulting in lower operation and support costs. Furthermore, the officials indicated that the units will be required during the transition to GPS which is expected to begin in 1985 and continue through the early 1990's.

DOD EFFORTS TO IDENTIFY USERS IS NOT COMPLETED

Although DOD has consistently emphasized the need for developing valid user information, an analysis of the contributions to be offered by the GPS to individual users had not been completed as of December 1978. In 1977 and again in 1978, DOD estimated the number of GPS users to be 27,000. This estimate assumed that almost all military aircraft, ships, and some land forces would be users of the system.

During our review, we were unable to track the estimated 27,000 users to specific missions and/or individual weapon systems that need the increased capability offered by GPS. This inability to track to individual users reflects the origin of the program; i.e., unmet needs and identified deficiencies of specific individual users were not the driving force behind the program being initiated.

In commenting on our draft report, DOD officials said that each service is now identifying individual users (weapon systems) and missions that could benefit from GPS being deployed. They further said that the data will be available in time for DSARC II.

The efforts to identify users are oriented toward developing a justification for GPS to enter full-scale engineering development. This is contrary to the normal acquisition practice. Usually users are the original driving force for a new system to be developed.

We found that individual commitments within the services to use the system have been slow in developing. DOD officials believe, however, that this interest will increase as user confidence grows based on the GPS validation phase testing.

Several factors contribute to the slowness of individual commitments to using GPS. These include uncertainties concerning

--the cost of the user equipment,

--if and when the system will be deployed,

--reliance on an external navigation system (self-contained systems are often preferred),

--general reluctance to accept a new system until it has been extensively demonstrated, and

--the benefit of investing in GPS compared to other weapon system needs within the individual services.

CONCLUSIONS

DOD plans a DSARC II review in May 1979 to consider whether GPS should be developed. We are concerned that the soundness of the pending decision to proceed with development could be jeopardized if the uncertainties pertaining to improved force effectiveness and potential cost savings are not resolved. We believe these issues must be resolved before making a decision to proceed with the program.

DOD is currently in the process of studying the user needs, force effectiveness, and replacement plans in preparation for the May 1979 DSARC review. However, considering the 5 years previously available for these studies, and in view of the limited time remaining prior to this DSARC review, we are concerned about the completeness and depth of coverage of these DOD-wide studies.

DOD officials are confident that the following information will be available in time for the DSARC II review:

--Navy, Army, and Air Force GPS requirements documents which can be a basis for establishing unmet military navigation needs.

--An update to the Decision Coordinating Paper with credible estimates on user numbers, cost, and availability schedule.

--Complete life-cycle cost estimates for GPS including users' equipment and operational and support costs.

--Plans for phaseout of existing navigation systems that GPS would replace.

--Studies to quantify the mission effectiveness benefits expected from GPS.

RECOMMENDATIONS

We recommend that the Secretary of Defense determine that the following information has been adequately developed and analyzed before deciding on whether to proceed into full-scale engineering development. Specifically:

--The individual military users are identified, and these users make specific commitments on how they will use the system.

--Force effectiveness benefits cited in any justification for acquiring GPS are supported by a well defined need or significant savings.

--Any cost savings attributed to replacing existing navigation systems are supported by specific commitments and plans for the phaseout of these systems.

In assessing the need for GPS, we recommend that the Congress require the Secretary of Defense to provide the following information when considering requests for fiscal year 1980 full-scale engineering development funds.

--Identify the individual weapon systems that will use the GPS, and for each of these users, identify

  --what required force effectiveness improvements will result,

--what commitments have been made by the services to eliminate alternative navigation systems, and

--what net potential cost savings have been identified after all life-cycle costs have been considered.

CHAPTER 3

GPS PROGRAM ESTIMATE NEEDS REFINEMENT

The current Air Force estimate for the GPS program is $1.7 billion. This amount is $900 million above the original 1973 estimate. Included in this estimate are

--development costs,

--ground station and initial 24-satellite acquisition costs, and

--ground station operation costs through fiscal year 1986.

Other related costs, roughly estimated by the Air Force to be $2.5 billion, will be added to this $1.7 billion program estimate in time for the DSARC II review in May 1979.

CURRENT COST ESTIMATES

The estimated program cost for which detailed estimates exist has about doubled since program inception--from $.81 billion in December 1973 to an estimated $1.7 billion in 1978. Cost estimates for the validation and full-scale engineering development phase have not significantly changed within the last year. However, cost estimates for the production phase have increased significantly--over $200 million during the last year.

The cost increases since the program began in December 1973 are shown in the following table:

Partial GPS Cost Estimates (note a)

Phase	Original estimate Dec. 1973	Revised program estimate Feb. 1978	Increase from 1973 to 1978
	(millions)		
Validation	$177.9	$ 406.3	$228.4
Full-scale engineering development	253.4	679.6	426.2
Production	383.1	659.1	276.0
Total	$814.4	$1,745.0	$930.6

a/Then-year dollars.

A brief explanation of these increases from the original estimate follows. Further details are included in Appendix II.

Validation--The increased costs were caused by added scope and tasks, cost overruns precipitating a 1977 program restructure, and inflation. The added scope and tasks include such things as alternate user equipment development, and additional satellite and launch vehicle procurement to support the fleet ballistic missile accuracy improvement program. User and control segment developmental problems overran costs, created a fund shortage and caused the restructuring.

Full-scale engineering development--Program scope changes have mostly caused the increases. Additional user, space, and control segment developmental efforts are the main scope changes. The increased control segment efforts necessitated additional military construction funds. Also, the original program plan did not include Army and Navy funding for user equipment development. Additional funds might be needed from the Army and Navy to fund dual contractor user equipment development.

Production--The increased estimates were caused by (1) procurement of additional satellites at increased unit costs; (2) higher than expected military construction costs for control facilities, additional control facility software acquired in a shorter time period; and (3) recognition of user equipment integration kit development costs.

OTHER RELATED COSTS

In addition to the $1.7 billion discussed above, roughly $2.5 billion of related costs must be considered as part of the investment in the GPS program. Following is a breakdown of this $2.5 billion estimate, in mixed-year dollars, that was provided during our review:

--The procurement, integration, operation and support costs of user equipment estimated by the program office to be $1.7 billion (fiscal year 1975 dollars) for 27,000 users. These estimates are being revised.

--The cost of replenishment satellites to maintain the 24-satellite constellation 10 years past initial operating capability estimated by the program officials to be $575 million (then-year dollars).

--The Space Shuttle launch costs for the production phase and replenishment satellites estimated by a Space and Missile Systems Organization independent cost analysis team to be $270 million (fiscal year 1977 dollars).

CONCLUSION

As a result of these program related costs not being available in then-year dollars, it is appropriate to conclude that the current estimated cost of the GPS program is in excess of $4.25 billion--$1.7 billion plus $2.5 billion plus escalation. In commenting on our draft report, DOD officials stated that an estimate in then-year dollars for the total program will be available for the DSARC II review.

RECOMMENDATION

We recommend that the Secretary of Defense determine that all related system costs are computed and incorporated in the total estimated cost of the program, before deciding on whether to proceed into full-scale engineering development.

CHAPTER 4

TEST AND PERFORMANCE STATUS--

AVAILABLE RESULTS ARE PROMISING

Test results available as of October 1978 are very promising, but are based on limited testing.

Normal use of GPS requires receiving signals from four satellites, and the program plans call for final test results to be based on four-satellite test data. During our review, available results were based primarily on one satellite used in conjunction with ground equipment which simulated the three remaining satellites. These test results were promising, but additional tests with three and four satellites will be needed to confirm that performance accuracy using satellites does not have unexpected degradations over accuracies obtained with ground simulations. This data will be available beginning in January 1979.

TEST RESULTS

Navigation accuracies of better than 3 meters have been achieved using one satellite along with ground simulation. This accuracy is better than was expected. However, program officials anticipate that this accuracy will decrease with more realistic four-satellite testing--probably from 3 meters to an estimated 9 meters--but still better than the validation phase goals. Program officials stated that an accuracy of far better than the 45 meters, the validation phase minimum accuracy goal, will be achieved but they need some results from the three-satellite tests to confirm performance estimates.

In commenting on our draft report, program officials stated that some results from the three-satellite tests had been obtained in November 1978, and initial results indicate an accuracy of better than 10 meters. Furthermore, we were informed that the fourth satellite was launched in early December 1978 and is expected to be operating by January 1979 to support final system-level testing.

TEST DELAYS

During 1978 delays have occurred in achieving a four-satellite constellation, resulting in about a 3-month delay in obtaining four-satellite test data. The delays occurred because one satellite failed in space and two other satellites experienced launch delays averaging 2 months due to

manufacturing problems. Initial four-satellite test data, originally expected in October, will not be available before January 1979.

Because of satellite delays, program officials made plans for providing three-satellite testing in order to maintain the DSARC II schedule. However, since DSARC II has been delayed 3 months to obtain data on replacement of current navigational equipment and on unique Army test requirements, program officials now plan to present four-satellite test data at DSARC II.

TEST FACILITY CONCERN

Program officials have concerns about available manpower resources at the test facility. Plans are being explored to minimize the possibility these shortages will delay completing the validation phase tests.

GPS is being tested at the Army Proving Ground at Yuma, Arizona. The Yuma facility's work force has been cut by one-third in the last 2 years. So far, the Yuma facility has been able to support GPS tests by using part-time students and overtime. However, Yuma officials predict increasing delays in processing and analyzing GPS test data as the scope of the tests increase and other programs place competing demands on Yuma's resources.

VULNERABILITY TO ENEMY COUNTERMEASURES

Radio navigation aids by their very nature are vulnerable to enemy countermeasure. This condition has been recognized by the Air Force since the beginning of the program and, consequently, special attention has been given to developing a high jam-resistant system. Program officials stated that preliminary test results indicate jam-resistance is slightly better than required by their specifications. They attributed this success, in part, to greater strength of the satellite signal than anticipated.

CHAPTER 5

GPS ACQUISITION SCHEDULE

Since the program was initiated in December 1973 concept validation has slipped about 14 months. Three months of this delay have occurred in the last year. Estimates for initial and fully operational capability dates have slipped about 13 months. A 24-satellite operational system is now expected in September 1986.

The following table compares the original schedule with the current schedule for all three phases of the GPS program.

Comparison of Original Schedule Events with Current Schedule for the Overall Program

Phase	Original schedule Dec. 1973	Current schedule Oct. 1978	Delay (months)
Validation			
Approval	a/Dec. 1973	-	-
Acquisition Council's review for beginning full-scale engineering development	Mar. 1978	May 1979	14
Full-scale engineering development			
User equipment 4-contractor competition to start	Not planned	a/Mar. 1978	-
User equipment final contracts awards (2 contractors)	Jan. 1979	Jun. 1979	5
Begin field testing user equipment	June 1980	Nov. 1981	17
Begin operational master control and upload station operations	June 1981	Apr. 1983	22
Acquisition Council's review for beginning production:			
(user equipment)	Jan. 1982	Apr. 1983	15
(satellites)	Jan. 1982	Mar. 1981	-
Production			
Begin follow-on test on evaluation user equipment	Nov. 1983	Oct. 1984	11
Initial operational capability (18 statellites)	Aug. 1984	Sept. 1985	13
Full 24-satellite operation	Aug. 1985	Sept. 1986	13

a/Actual occurrence.

APPENDIX I

VALIDATION PHASE USER EQUIPMENT

Equipment nomenclature	Performance capabilities	Potential use	Contractor
X set	High accuracy High dynamic Simultaneous 4-channel reception Auxiliary sensor option (X-aided set)	Tactical aircraft Missiles Submarines Aircraft carriers Helicopters	a/General Dynamics (Magnavox)
Y set	High accuracy Medium dynamic Sequential single-channel Auxiliary sensor option (Y-aided set)	Naval combat ships Refueling aircraft Helicopters	General Dynamics (Magnavox)
Z set (low cost)	Medium accuracy Medium dynamic	Naval support vessels Search and rescue and cargo aircraft	General Dynamics (Magnavox)
Manpack	Portable High accuracy	Ground troops Land vehicles	General Dynamics (Magnavox) Texas Instruments (alternate design
High dynamic set	High performance 5-channel reception (alternate design - similar to X set)	Airborne applications	Texas Instruments
Jam-resistant set	High performance 5-channel reception Directional antenna Doppler velocity compensation	Environments requiring high antijam characteristics	Collins Radio

a/Magnavox Corporation is under subcontract to General Dynamics for user equipment development.

CHANGES FROM ORIGINAL COST ESTIMATE

VALIDATION PHASE

Cost element	Original estimate Dec. 1973	Added scope and tasks	Cost increase at restructuring (note a)	Revised estimate Feb. 1978	Increase from original to Aug. 1978 approved program
	(millions)				
Spacecraft-support	$ 85.3	$ 82.9	$ 3.7	$171.9	$86.6
Launch vehicles	28.1	18.2	6.4	52.7	24.6
Control/user equipment	47.9	53.6	36.5	138.0	90.1
Testing	11.3	.3	.2	11.8	.5
Technical support	5.3	10.9	12.2	28.4	23.1
1977 escalation index changes	-	-	-	3.5	3.5
Total	$177.9	$165.9	$59.0	$406.3	$228.4

a/Then-year dollars.

APPENDIX II

CHANGES FROM ORIGINAL COST ESTIMATE

FULL-SCALE ENGINEERING DEVELOPMENT PHASE

Cost element	Original estimate Dec. 1973	Revised estimate Feb. 1978 (note a)	Increase/(Decrease) from original to Feb. 1978 Program
	(millions)		
Satellite	$126.2	$216.8	$ 90.6
Launch vehicle	44.3	32.3	(12.0)
Control	19.7	91.4	71.7
User equipment/testing	55.4	203.1	147.7
Technical support/other	7.8	-	(7.8)
Military construction	-	36.0	36.0
Service unique user equipment development, integration, and testing:			
Navy	-	45.2	45.2
Army	-	54.8	54.8
Total	$253.4	$679.6	$426.2

a/Then-year dollars.

APPENDIX II

CHANGES FROM ORIGINAL COST ESTIMATE

PRODUCTION PHASE

Cost element	Original estimate Dec. 1973	Revised estimate Feb. 1978 (note a)	Increase/(Decrease) from original to Feb. 1978 Program
	(millions)		
Satellite	$219.2	$584.7	$365.5
Launch vehicle	110.6	-	(110.6)
Control	23.6	59.8	36.2
Testing	23.5	-	(23.5)
Technical support	6.2	-	(6.2)
Military construction	-	3.0	3.0
User integration	-	11.6	11.6
Total	$383.1	$659.1	$276.0

a/Then-year dollars.

APPENDIX II

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