094104

Extra

REPORT TO THE CONGRESS

B-163058

Army Air Defense: The SAM-D Program B-163058

Department of Defense

BY THE COMPTROLLER GENERAL OF THE UNITED STATES

~~710982~~ 094104

FILE COPY - COMP. GEN.

JUNE 20, 1973

COMPTROLLER GENERAL OF THE UNITED STATES
WASHINGTON D C 20548

B-163058

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

This is our report entitled "Army Air Defense The SAM-D Program," a declassified version of a classified report issued on May 7, 1973 The Department of Defense is responsible for administering this program.

For a more comprehensive understanding of the matters discussed, see the classified report

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, the Secretary of Defense, and the Secretary of the Army

Elmer B. Staats

Comptroller General
of the United States

This is a declassified version of a classified report issued May 7, 1973 Classified information has been omitted as indicated by blanks

Contents

FIGURE

TABLE

ABBREVIATIONS

ABM	Antiballistic missile
AD	air defense
ADEB	Air Defense Evaluation Board
ARM	antiradiation missile
ASM	air-to-surface missile
ATBM	antitactical ballistic missile
CONUS	continental United States
DCP	development concept paper
DIA	Defense Intelligence Agency
DDR&E	Director of Defense Research and Engineering
DOD	Department of Defense
DSARC	Defense Systems Acquisition Review Council
ECCM	electronic counter-countermeasure
ECM	electronic countermeasure
EMP	electromagnetic pulse
GAO	General Accounting Office
HAWK	homing all-the-way killer
MN-ED	materiel need - engineering development
SAM	surface-to-air missile
SAM-D	surface-to-air missile development
TBM	tactical ballistic missile
TRIAD	triangular air defense
TVM	track-via-missile
USACDC	U S Army Combat Developments Command

COMPTROLLER GENERAL'S REPORT TO THE CONGRESS

ARMY AIR DEFENSE
SAM-D PROGRAM
Department of Defense
B-163058

D I G E S T

WHY THE REVIEW WAS MADE

GAO made this review early in 1972 to assist the Congress in determining whether the proposed SAM-D (surface-to-air missile development) system, now in the engineering-development stage, will fulfill, at an acceptable cost, an essential air defense need for the United States

Subsequently, the Chairman, Research and Development Subcommittee, Senate Armed Services Committee, asked GAO for specific information on the SAM-D program before the hearings to be held in the spring of 1973 (See app II)

The Army is fielding a new system, the Improved HAWK (homing all-the-way killer), and is developing a new one, the SAM-D, which will require greater resources SAM-D will replace the Improved HAWK and the Nike Hercules systems

Background

The Army is using advanced technology in the SAM-D system for use starting in the 1980s, the system will be capable of operating in a severe electronic countermeasure environment and against massive attacks The Department of Defense (DOD) justifies the SAM-D on the basis that it will be more cost effective than other systems, including fielding the Improved HAWK system in greater numbers

FINDINGS AND CONCLUSIONS

Need

There are differences of opinion among officials in DOD about the extent of the enemy threat to be countered by air defense systems, including the SAM-D system

The Defense Intelligence Agency estimates a lesser enemy threat to be countered by the SAM-D system than the threat estimated by the Army (See p 33)

Operations

1 A single Improved HAWK radar can scan a greater area than a single SAM-D radar (See p 25) The Army is studying ways to increase the SAM-D radar coverage and ways to increase radar survivability against enemy antiradiation missiles (See p 38)

2 Reloading times are significantly longer for the SAM-D system than for the Improved HAWK However, an Improved HAWK battery is easier to overwhelm than a single SAM-D fire section, since the Improved HAWK can engage fewer targets concurrently than the SAM-D system (See p 26)

3 The SAM-D system can track a significantly greater number of targets than can the Improved HAWK (See p 26)

Tear Sheet

JUNE 20, 1973

4 The SAM-D system also has a longer range, a higher altitude capability, and a faster firing rate than the Improved HAWK (See p 30)

5 The Army is planning to use fewer personnel to deploy the SAM-D system (See p 29)

Testing

Current U S Army and Office of the Secretary of Defense policy regarding development of a new weapon system stresses the importance of testing components in advanced development to avoid costly mistakes in engineering development and procurement

The Army requested, and the Director of Defense Research and Engineering approved, the deletion of certain advanced development testing originally included in the test plan The Director based his approval on the fact that delays had occurred in the program plan due principally to funding shortages These delays resulted in a less mature design model available for testing It was felt by the Director that testing of this model would have significantly increased the costs of the tests and decreased the benefits to be gained over that previously envisioned

For example, missile flight-testing of the critical track-via-missile guidance was postponed until 1974 Testing the sensitive warhead-fuzing interface will not take place until the SAM-D system is well into engineering development By the time the missiles are flown to test the guidance, and by the time the fuzing interface test is made, about $793 million will have been invested in the program

The Army stated that it had gained assurance through simulation and captive flight-testing that its request to postpone the missile flight-testing was sound, it expressed confidence that its revised test plan would be successful (See p 45)

Past experience has shown that decisions to forego testing during advanced development have often resulted in substantially increased costs and in lower performance accomplishments

Cost

The SAM-D system, for various reasons--most of which are similar to those identified with other large programs where the technological state of the art is challenged--has shown a severe drop in the number of units to be procured Total program cost has increased about 9 percent since the 1967 development estimate

The program unit cost of these fire sections is more than three times the unit cost in the development estimate According to the Army's variance analyses, the reasons for the increased unit cost are (1) escalation, 42 percent, (2) reduced quantities to be purchased, 27 percent, and (3) correction of prior estimating errors and engineering and schedule changes, 31 percent (See p 8)

RECOMMENDATIONS OR SUGGESTIONS

This report contains no recommendations

AGENCY ACTION AND UNRESOLVED ISSUES

GAO provided copies of its draft report to representatives of the

Office of the Secretary of Defense and the Department of the Army for review and discussion Their comments are incorporated as appropriate

MATTERS FOR CONSIDERATION BY THE CONGRESS

The issues discussed in this report on the Army's acquisition of its proposed air defense system, SAM-D, are critical to the success of the program.

The Congress may want to consider

--What assumptions were made justifying that the SAM-D's greater engagement capability would offset its slower reloading time

--Why the Army used its threat assessment rather than DIA's and whether a new analysis should be made that would include consideration of all support and systems that would be available, including ground and air, to counter the threat beyond 1980.

--Whether the Army has left its forces and the assets it is to protect vulnerable to attack by developing a system, namely the SAM-D, that has limited radar coverage.

--Whether the SAM-D, or any other air defense system for that matter, can survive or be effective in an environment where antiradiation missiles are used.

--Whether the Army is still assured as to the prospects of being able to operate the SAM-D with fewer personnel and attain simplified maintenance in view of changes in quantities to be acquired and changes in performance characteristics

--Whether the decisions to defer testing of critical components, i e , the warhead-fuzing and guidance subsystems until a considerable expenditure of funds has been made is justified in the light of past experience

--Whether the current trend of rising costs on the SAM-D program can be curtailed and whether continued rising costs would impact on the capabilities and quantities of fire sections acquired

--Whether a new cost effectiveness study is warranted in view of the changes made to the SAM-D performance characteristics, quantities, and additional changes contemplated, as well as the product improvement program on the Improved HAWK

Another matter of particular concern that the Congress may wish to examine relates to the Mutual and Balanced Force Reduction program presently under negotiation Since the need for the SAM-D is predicated, in part, on the Army's assumption that its forces in Europe will be increased, reduction in the size of these forces and the Warsaw Pact forces could impact significantly on the quantities of SAM-D fire sections needed in that area

Tear Sheet

CHAPTER 1

INTRODUCTION

NATURE OF TACTICAL AIR DEFENSE

Tactical air defense (AD), a multiservice mission, is complicated because the enemy can rely on surprise to attack first Enemy airborne weapons are mobile and fast and can be concentrated or dispersed at will Enemy countermeasures and friendly counter-countermeasures abound as each side tries to confuse each other with spurious electronic signals and other deceptions The AD command, control, and communication network must link the various Army and Air Force defense weapons throughout the theater for quick reaction to enemy raids Identifying the enemy in the crowded air space of a war theater and avoiding friendly losses are pervasive problems

The Joint Chiefs of Staff define "anti-air-warfare mission" as

> " * * * that action required to destroy or reduce to an acceptable level the enemy air and missile threat It includes such measures as the use of [manned] interceptors, bombers, antiaircraft guns, surface-to-air and air-to-air missiles, electronic countermeasures, and destruction of the air or missile threat both before and after it is launched. Other measures which are taken to minimize the effects of hostile air action are cover, concealment, dispersion, deception (including electronic) and mobility "[1]

---

[1]Joint Chiefs of Staff Pub 1, Dictionary of United States Military Terms for Joint Usage (Washington the Government Printing Office, Aug 1, 1968), p 19

LFFECT ON RESOURCES

Since the enemy can use a wide range of attack modes in a given war theater, friendly forces must keep great resources in manpower and systems to protect valuable assets Some of these assets may be quite safe (as seen in retrospect), but uncertainty about enemy intentions requires the assignment of ADs to these assets anyway Nevertheless, AD coverage cannot be total and complete because of the immense resources in manpower and equipment that would be required to defend all assets The mix of AD weapons must be that which the budget allows and the tactician recommends

SCOPE

We interviewed officials within the Department of Defense (DOD), as well as outside experts, to get their views on how the overall tactical AD mission ought to be executed, the number of AD weapon systems currently deployed, and what future developments should provide We reviewed reports pertaining to cost effectiveness, survivability, and combat utility of existing and proposed AD weapons

Most DOD studies on tactical AD are based on activities in central Europe, because DOD believes the threat to the field army is most representative Therefore our report concerns the problem of defending the field army and other valuable assets in that theater of operations where the 7th Army is located

The roles of the weapon systems (Basic HAWK (homing all-the-way killer) and Nike Hercules) currently deployed by the field army are discussed in passing with greater attention given to the Improved HAWK The report's main emphasis is placed on the surface-to-air missile development (SAM-D) now in engineering development

MISSION OF THE SAM-D SYSTEM

The SAM-D system will replace the Nike Hercules and the Improved HAWK in providing Army AD in the field and

the continental United States (CONUS) In the field army, SAM-D system defense will be complemented by short-range, low-altitude forward-area AD weapons and will be integrated with the U S Air Force in the overall AD of the theater of operations In CONUS, the SAM-D system will provide defense of high value complexes along the periphery and will be integrated with other AD forces The advanced features of the SAM-D system will provide an increased capability against distant targets, massive attacks, and electronic countermeasures (ECMs) all with less manpower and maintenance resources than employed by the Improved HAWK and Nike Hercules

STATUS OF THE SAM-D PROGRAM

Cost

The preliminary December 31, 1972, Selected Acquisition Report for the SAM-D system shows a total current program estimate of $4,377 million.

	Amount (millions)
Research, development, test, and evaluation	$1,156 2
Procurement (includes spares)	3,167 6
Construction	53 3
Total	$4,377 1

The 1967 development estimate[1] called for a total program cost of $4,031 million, computed in 1967 constant-year dollars. Although the currently estimated cost has increased by about 9 percent, the planned procurement of (1) SAM-D tactical fire sections has decreased from (68 percent) and (2) missiles has decreased from to (52 percent).

---

[1]Made during the period in which preliminary design and engineering were verified or accomplished and represented the then-total program estimate

The program unit cost of a tactical fire section is now about , which is three and one-half times the development estimate of According to the Army's variance analyses, the reasons for the unit cost increase are (1) escalation, 42 percent, (2) reduced quantities, 27 percent, and (3) correction of prior estimating errors and engineering and schedule changes, 31 percent

Schedule

The Selected Acquisition Report of December 31, 1972, shows the following SAM-D milestone data

Milestone	Development estimate (Mar 1967)	Current estimate (Dec 1972)	Delay (months)
Initiation of advanced development	-	May 1967	-
Development concept paper (DCP) thresholds			
Contract for engineering development	May 1967	Mar 1972	58
Control test vehicle flight initiation	-	Nov 1973	-
Advanced development/fire control group guidance flight initiation	-	May 1974	-
Engineering development fire control group system demonstration flight initiation	-	Nov 1975	-
Research and development acceptance test	-	Dec 1976	-
DCP milestones			
Milestone No 1--cumulative cost $263 million at June 1973	-	June 1973	-
Contract milestones			
Complete model of demonstration fire control group	-	Sept 1973	-
Limited production contract award decision	May 1971	June 1977	73
Production contract award decision	-	3d qtr 1979	-
Initial operational capability			76

CHAPTER 2

ALTERNATIVE AD SYSTEMS

The Army concludes that the currently deployed Basic HAWK and Nike Hercules systems cannot defeat the threat in Europe during the 1980-90 period The Army stated in a recent study (see ch 3) that either the Improved HAWK or the SAM-D system could provide the needed capabilities given sufficient numbers deployed [1]

IMPROVED HAWK

The Improved HAWK system is an all-weather, mobile weapon capable of automatically acquiring, identifying, tracking, and intercepting targets flying at speeds of knots at ranges of about miles[2] away and at altitudes up to about feet in a non-ECM environment

The Army began deployment of the Improved HAWK systems in 1972, to provide low- and medium-altitude AD for the field army This was a major effort to provide new missiles, improved continuous wave acquisition radars, and automatic information control. This system is a modified version of the Basic HAWK having, according to the Army, the following advantages

1. Quicker reaction to the threat

---

[1]Secret Report by the U.S Army Combat Developments Command (USACDC), Air Defense Evaluation Board (1980-1990) (U) Summary Report, Vol. I (Washington USACDC, Nov 1970), p 38, hereinafter referred to as ADEB Summary.

[2]All miles cited in this report are nautical miles A nautical mile equals 6,080 feet

2 Improved target evaluation, threat orderings,[1] and fire control capabilities

3 Faster target-speed handling capabilities

4 Greater lethality and effectiveness against multiple as well as single targets.

5 Longer range and higher altitude and better missile performance against maneuvering targets

6 Increased missile reliability, easier maintainability, and reduced missile logistic requirements.

7 Better electronic counter-countermeasure (ECCM) qualities

The Army plans to deploy two different configurations for operational purposes of the modified system the Improved HAWK battery (two fire sections) and the Improved HAWK-TRIAD (triangular air defense) battery (three fire sections) (See pp 11 and 12) The TRAID battery has one more fire section than the other version and can be divided into three operationally independent fire units,

For better understanding, we will discuss the smaller of the two configurations

Target acquisition and fire control group

The Improved HAWK system has two acquisition radars each of which continuously rotates 360° to provide data for target detection, identification, and evaluation. Another radar for range only provides critical threat information under certain ECM conditions

The Information-Coordination Central (see p 11) houses automatic data processing equipment, communications, and

[1]Arrangement of targets by priority

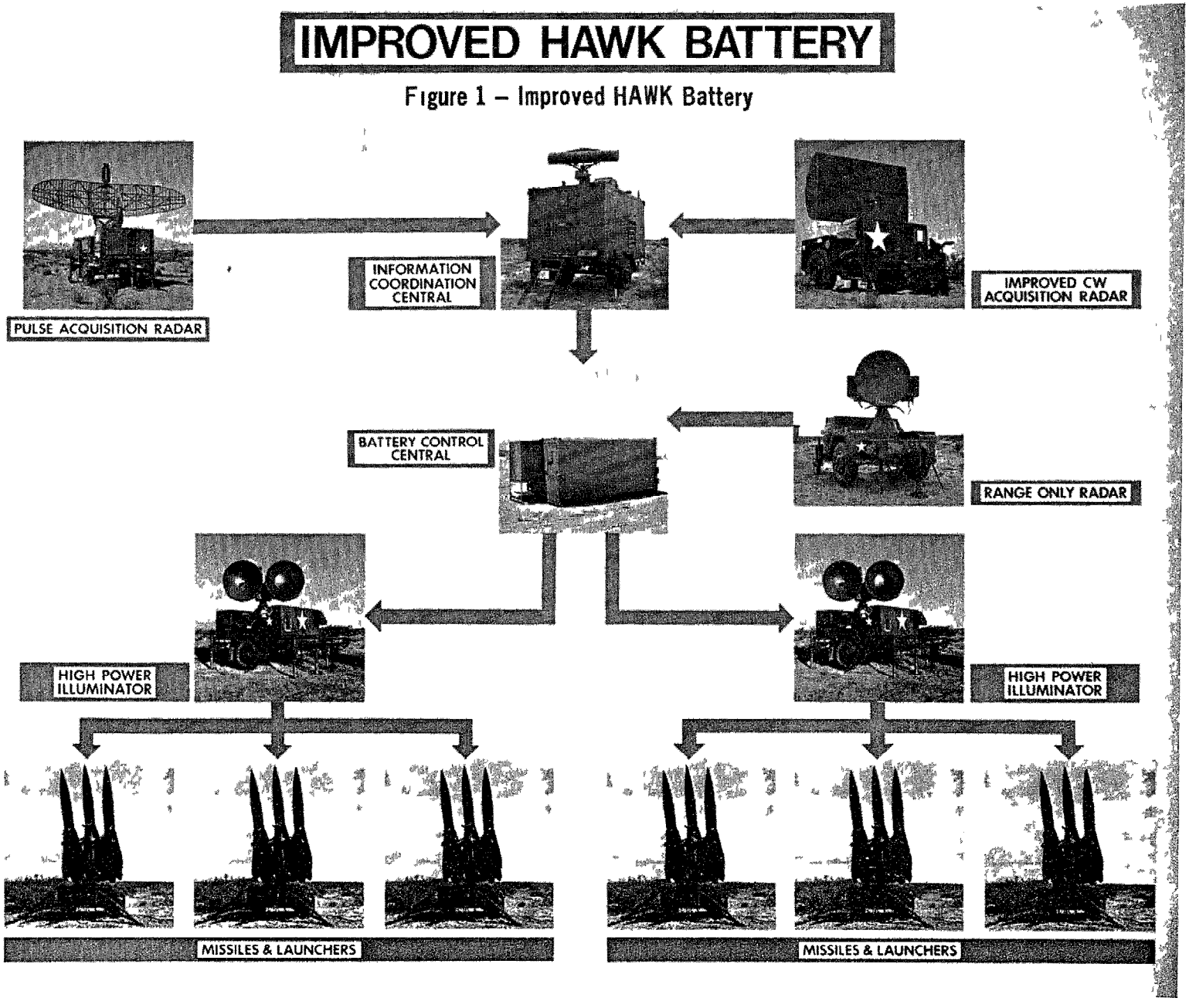


Figure 1 – Improved HAWK Battery

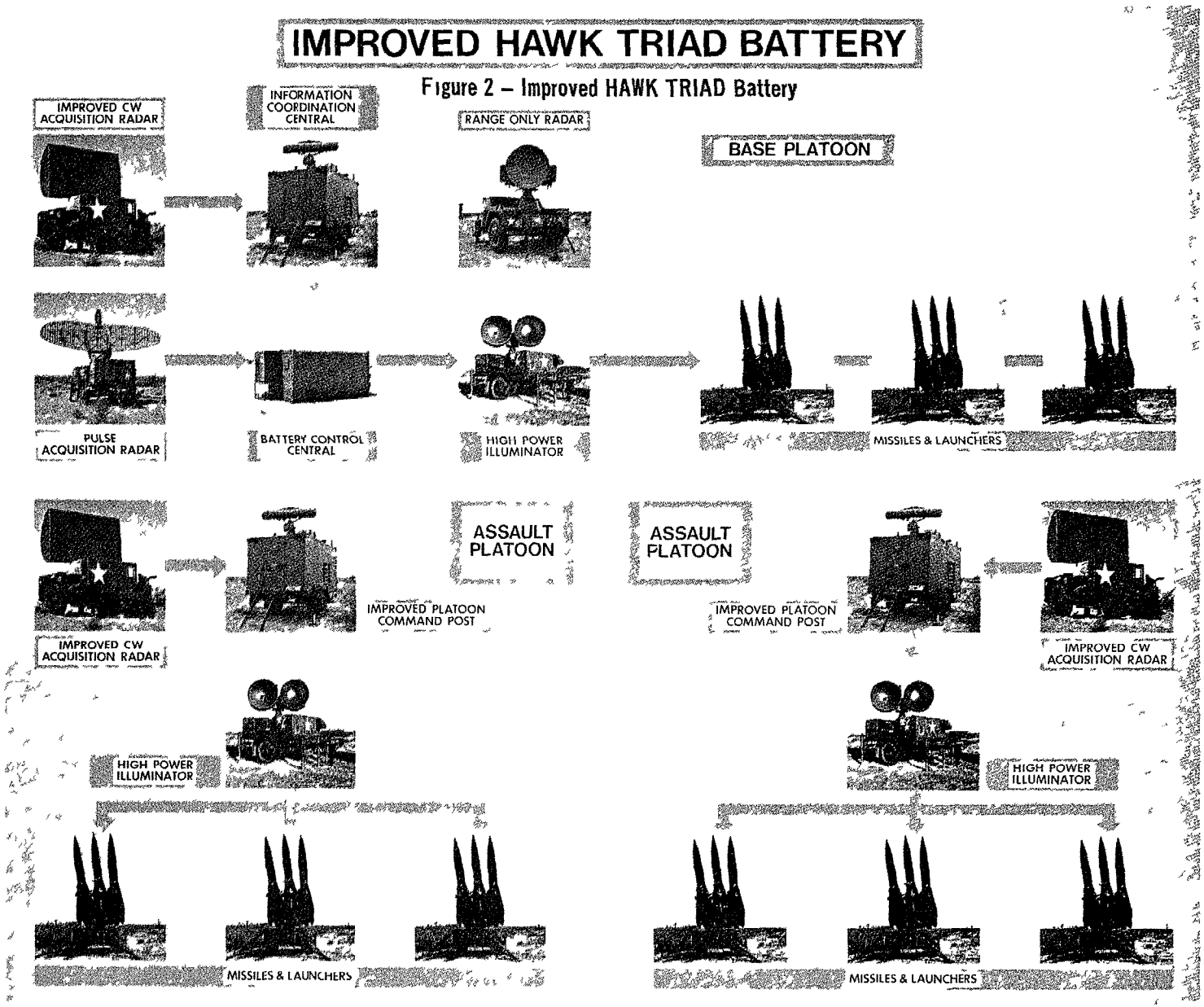


Figure 2 – Improved HAWK TRIAD Battery

equipment for distinguishing friendly aircraft from enemy aircraft The Central permits fast reaction and automatic operations from target acquisition through missile launch and assigns targets to each of two fire sections

A Battery-Control Central (see p 11) provides tactical control of the battery and over each fire section and allows the Improved HAWK system to operate automatically, semiautomatically, or manually by the crew

Launching and handling group

Each of the two fire sections has three missile launchers (nine missiles in each section) The launcher designated to fire activates and aims a missile into an intercept course with the target and launches it A tracked loader vehicle in each fire section can reload a launcher in minutes additional ready missiles, all of which can be loaded in about minutes, are available on storage pallets

Guidance group

Using target data transmitted through the Information-Coordination Central from the acquisition radars, a guidance-illuminator radar in each fire section reacquires, tracks, and provides a reference signal to the missile The reference signal is compared to the radar energy reflected by the target The missile follows the reflected energy until target intercept

Test equipment group

The Improved HAWK's ground-support equipment contains built-in test equipment The missile is a certified round, i e , designed to require no field test or maintenance.

Program cost

The December 31, 1972, Selected Acquisition Report on Improved HAWK estimated the total program cost at $772.5 million.

	Amount (millions)	
Research, development, test, and evaluation		$106 6
Procurement		
Missiles (quantity	$344.4	
Modified Basic HAWK ground sets (quantity	297 5	
Initial spares	22 7	
Total procurement		664 6
Construction		1 3
Total program		$772 5

Growth potential

According to the Army, it is conducting product improvement studies on the Improved HAWK, but as concluded previously, upgrading the system still will not make the Improved HAWK as cost effective as the SAM-D system

SAM-D

According to the Army's Materiel Need - Engineering Document (MN-ED)

> "The Army requires an advanced surface-to-air guided missile system capable of operation in an electronic countermeasures (ECM) environment, which provides a high single shot kill probability and the capability to conduct multiple simultaneous engagements against the high performance air-breathing [1] targets most likely to be

[1]System requiring atmosphere to support combustion when airborne such as aircraft

encountered by deployed U S forces during the 1980-1990 period "[1]

In 1970 the Army convened an ad hoc Air Defense Evaluation Board (ADEB) to review the existing AD systems and the Improved HAWK and the SAM-D development programs The findings of ADEB formed the basis for the continued development of the SAM-D

The SAM-D program is striving for an amalgamation of capabilities unprecedented in tactical surface-to-air operations For example, its speed is expected to be substantially faster than that of any known counterpart--twice as fast as the Improved HAWK Furthermore, its very powerful radar is to combine the previously separated tasks of surveillance, target-tracking, and missile guidance

---

[1]Secret Report by USACDC, Materiel Need - Engineering Development MN-ED for Surface-to-air Missile Development (SAM-D) (U), (Ft Belvoir, Va , USACDC Sept 18, 1972), p 1

History of development

After making a number of unsuccessful attempts during the 1950s and early 1960s to definitize a land-based weapon system to defeat tactical ballistic missiles (TBMs) or a combination of TBMs and high-speed aircraft, the Secretary of Defense reoriented this effort in 1964 and renamed the project as SAM-D The SAM-D system was to be capable of defeating a aircraft of the type--and the adequacy of the by-product antitactical ballistic missile (ATBM) capability was to be determined.

> "Development of the SAM-D system began although there was uncertainty over the utility of the system, the character of the threat which was to be countered, and the capabilities of companion weapons with which the system would operate Because of these uncertainties, in May 1967 the Secretary of Defense delayed the system's entry into full-scale development Instead, the system was placed in an advanced development program to be conducted over a 3-year period After 2 years in the advanced development phase, the system was studied in March 1969 to determine whether it should enter full-scale development The Deputy Secretary of Defense directed that the system be continued in the advanced development phase through fiscal year 1970 and that the decision to place the system into full-scale development be deferred until fiscal year 1971 His position was that the system would not be needed until sometime later, the number of

batteries needed and how the system would be deployed in the field were unknown, and the system was neither fully defined nor justified "[1]

An Army Senior Officer Materiel Review Board in 1969 recommended proceeding with engineering development One of the five members held the view that the SAM-D system was unnecessarily costly and involved excessive technical risk because the threat was inflated and the design still embodied a great deal of sophistication particularly to counter TBMs

"In March 1970, the Army subjected the system to review by the Air Defense Evaluation Board The Board was directed to again analyze the threat that the system had to meet, to identify the air defense capabilities required to defend against this threat, and to identify existing air defense capabilities and deficiencies to meet the threat. The Board's report was approved by the Chief of Staff on November 19, 1970, and, in essence, confirmed the Army's position on the need for the SAM-D."[2]

In November 1970 the Army

were planned. The September 1972 MN-ED states

---

[1]Comptroller General of the United States, Acquisition of Major Weapon Systems (B-163058), (Washington, D.C., U S. General Accounting Office Mar. 18, 1971), p 17

[2]Ibid., p 18

"The system shall have an

"[1]

A recent Army decision, however, deleted the research and development and procurement funds for the nuclear warhead but directed that design and development of the ground support equipment and missile retain the minimum essential features to maintain the nuclear option

In March 1972 the Secretary of Defense approved the SAM-D system for engineering development and the commitment of about $563 million His decision was based on the DCP, the completion of advance development phase in December 1971, and the recommendation of the Defense Systems Acquisition Review Council (DSARC)[2] which reviewed the SAM-D system development

Figure 3 (p. 19) depicts the major milestones and gives a summary of management decisions in the evolution of the SAM-D system.

---

[1]MN-ED p 15.

[2]DSARC reviews developing weapon systems before each major milestone to determine whether the program's progress, cost effectiveness, technical approach, testing results, etc , favor a weapon's entry into the next phase of the acquisition cycle.

Figure 3 Evolution of the SAM-D System

PLATO- 1952-59

This was a mobile system for use against short and medium range ballistic missiles (from 25 to 1,000 miles) surface-to surface missiles and aircraft It was to have a nuclear warhead and was to provide defense in the 1960-70 period

FIELD ARMY BALLISTIC MISSILE DEFENSE SYSTEM -1960-62

This was a mobile system for use against ballistic missiles with ranges up to 1 080 miles as well as against the air supported threat The system was to be operative in the post-1965 period

ARMY AD- 1970--1962-64

This was a mobile system for use against the 650-mile-range ballistic missile It would provide a first intercept against a Mach 3 aircraft 55 miles from the battery

SAM D--OCTOBER 1964

This was a mobile system for use against an aircraft The system would also be used against the and would also have application in CONUS

SAM-D- MAY 1967 ADVANCED DEVELOPMENT

This was a mobile system for use against air-supported targets in the 1970-80 period It may be used in CONUS It would be capable of employing a nuclear warhead and would detect engage and destroy having ranges from

SAM-D- MARCH 1972 ENGINEERING DEVELOPMENT

This was a mobile system for use in the field army against air-breathing targets in the 1980-90 period and had an inherent capability with nuclear warheads It would be deployed in CONUS

SAM D- DECEMBER 1972 ENGINEERING DEVELOPMENT

The option to procure nuclear warheads was dropped The Army approved CONUS deployment of SAM-D fire sections (SAM-D nuclear and antimissile capability study DA--Dec 1972) (See p 8 for other scheduled events)

A SAM-D fire section (see p 20) contains the basic equipment necessary for the system to operate independently in conducting AD engagements or to be part of a centralized AD network, such as a SAM-D battalion

The principal components of a field army fire section consist of a fire control group (radar van, power unit, and weapons control unit) and five launcher units In addition, there are other items of equipment for maintenance, missile handling, and crew training to support the fire section All items of equipment are to be mounted on standard Army wheeled vehicles Presently two fire units will comprise a missile battery and three batteries comprise a SAM-D battalion

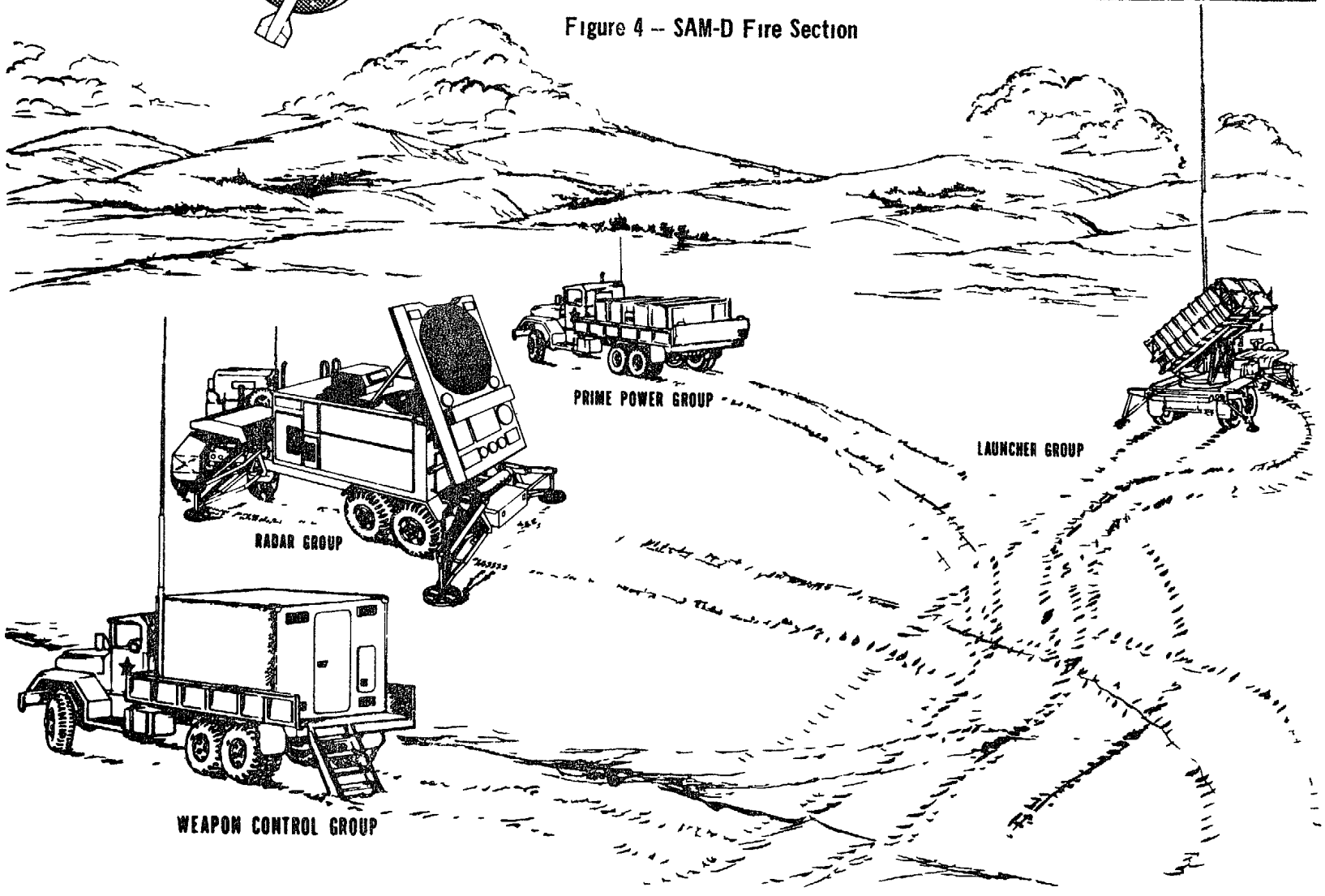
Fire control group

The fire control group contains all of the equipment necessary to conduct radar operations and to initiate and control missile engagements with the attackers

SAM D

FIRE SECTION

Figure 4 -- SAM-D Fire Section



Launcher unit

Each SAM-D launcher unit is to be capable of transporting and firing four missile rounds from individual missile cannisters. These cannisters protect the missile rounds while the launcher is being deployed and also serve as shipping containers and launch tubes. To enable the missiles to engage targets approaching from more than one direction, the launchers are to be turned ± 90° This movement is to be remotely controlled from the weapons control unit.

Radar

The one SAM-D radar unit is to combine search and surveillance, missile acquisition, track, and guidance, target illumination and tracking, and identification of friend or foe and ECM sensing It is expected to have the capabilities of (1) searching a volume of air space within in azimuth up to a maximum altitude of about feet and out to a range of approximately miles, (2) tracking simultaneously from targets within in azimuth, up to approximately an foot altitude and out to about a mile range, and (3) engaging up to targets simultaneously in the terminal guidance phase).

The antenna is to be mechanically turned so that the search sector may be changed without reorienting the entire radar unit A mechanical rotation of is to be accomplished in seconds

Missile

The SAM-D missile is to carry a high-explosive warhead The missile is to be wingless and designed for boost glide with very high acceleration and speed similar to antiballistic missile (ABM) systems. Maneuverability is to be provided by four control fins at the rear of the missile

Each missile is to be a certified round, that is, the missile should be so reliable that no periodic maintenance or testing will be necessary and that only a small percentage of missiles will fail in the field

Nuclear hardening

Criteria were established to protect the SAM-D system against nuclear effects of blast and thermal radiation as well as the concomitant gamma rays and electromagnetic pulses (EMP) The Defense Nuclear Agency's EMP awareness course publication[1] states

> "EMP has become a possible threat to nearly all sophisticated military systems * * *
>
> "Under the proper circumstances a significant portion of the energy released during a nuclear detonation can be made to appear as an Electro Magnetic Pulse (hence, EMP) having the same frequencies or wavelengths as those employed by most of our commercial radio and military system equipments
>
> "Two unique properties of EMP are of crucial significance -- its extremely great 'killing range,' EMP being capable of disabling electrical and electronic systems as far as 3000 miles from the site of the detonation, and the fact that EMP can cause severe disruption and sometimes damage when other prompt weapon effects such as nuclear radiation effects on electronics, blast, thermal effects, dust, debris and biological effects are all absent This means that a high-yield nuclear weapon, burst above the atmosphere, could be used to knock out improperly designed electrical and

---

[1]Defense Nuclear Agency (DNA), DNA EMP Awareness Course Notes (DNA 2772T) (Chicago, Ill. Illinois Institute of Technology (IIT) Research Institute, Aug 1971), p 1

electronic systems over a large area of the earth's surface without doing any other significant damage * * * "

Shielding electronic equipment against the effects of EMP is possible but is a very difficult procedure.

"Electronic equipment can be designed to be specially shielded by steel against nuclear EMPs, but this is an extremely costly and complex procedure * * *."[1]

Mode of operation

The computer is the central control element of the SAM-D system It directs the radar to conduct search and surveillance functions Suspected targets are placed under track by the computer (where all target data are stored). The targets are interrogated for identification of friend or foe, and, if they appear to be hostiles, they are subjected to threat evaluation. Once decided that a target should be engaged, the computer commands the launcher to ready and fire a missile. Within a few seconds after launch, the radar captures the missile in its beam and command guides it during midcourse flight.

The track-via-missile (TVM) guidance system takes over of the missile's flight.

---

[1]"Nuclear Electromagnetic Pulse Fears, "International Defense Digest, June 1972.

HIGHLIGHTS OF THE IMPROVED HAWK AND SAM-D PROGRAMS

The remainder of this chapter presents the major highlights of the Improved HAWK and the SAM-D programs and a discussion of those capabilities which the Army has expressed are required in a long-range AD system to counter the 1980-1990 threat

Development

The development of the Improved HAWK costs about $106 6 million, and, since the system is already in production and deployment has begun, the associated technical risks have been minimized The SAM-D system, however, has just entered engineering development, and the total estimated development cost is $1,156 million Approximately $598 million remains to be spent after fiscal year 1973 Certain critical capabilities of the system have yet to be demonstrated

Investment

Production has started on equipment to form batteries of the Improved HAWK from the Basic HAWK at a total estimated procurement cost of $665 million Procurement of tactical fire sections (batteries) of the SAM-D system at a cost of $3,220 9 million[1] is scheduled to begin at a low rate in 1977 after production approval from the DSARC

Operations

The Improved HAWK became operational in November 1972 with the initial deployment of units to the 7th Army and is to remain operational until replaced by the SAM-D system in The SAM-D system is scheduled to become operational in and, according to the Army, is being designed to remain in the field for as long as possible and will be capable of product improvement

---

[1]Includes $53 3 million for construction

Stated advantages of SAM-D

The Army's requirement for the SAM-D system is based on the system's (1) capability to engage multiple targets simultaneously, (2) capability to operate in an ECM environment, and (3) need for less manpower and maintenance than current systems

Multiple-target engagement

Saturation attacks by aircraft carrying decoys and antiradiation missiles may be employed to overwhelm friendly defenses According to the Army, the long-range tactical AD system needed to defend the field army starting in has a stated requirement to intercept at least targets simultaneously during every second period of multiple engagement. The Improved HAWK battery with its two fire sections can engage targets simultaneously, the SAM-D fire section is to engage .

The value of the multiple-engagement capability is measured by the ability of the system to provide high attrition of enemy aircraft over short periods This capability depends on the acquisition, tracking, and guidance features of the AD system and the degree of survivability of the system during the attack

Each of the Improved HAWK battery's two rotating acquisition radars (one for low and one for medium altitudes) provides a 360° coverage of the area to be defended. The SAM-D radar[1] possesses greater range than that of the Improved HAWK's radars, but it is capable of searching and acquiring only those targets coming within the sector it covers at any one time. To avoid being attacked from the sides or rear by the enemy, SAM-D fire units with their single nonrotating radars must be grouped to provide mutual defense or complemented

---

[1]The SAM-D fire section uses a single radar to perform all functions.

by other AD systems The radar can be mechanically turned to acquire targets coming from other directions It is expected to take seconds to turn and to be capable of firing seconds later

The Improved HAWK battery can function with the loss of one of its acquisition radars The capability in the medium- or low-altitude regime will be reduced, depending on which radar is lost

The loss of the SAM-D single radar, on the other hand, will put the fire unit out of action The Improved HAWK battery, with its two tracking radars, can simultaneously track two targets coming from opposite directions The SAM-D radar is capable of tracking targets, but only within its tracking sector The SAM-D system will engage targets out to a mile range, the Improved HAWK's range is about miles

Each of the Improved HAWK's tracking radars can guide a missile to intercept a single target at minimum intervals of seconds until the target is destroyed A second target can only be engaged by each radar after an intercept has been made The SAM-D radar is to guide up to missiles simultaneously, if the targets are all within the same tracking sector

The Improved HAWK battery has 18 missiles on launchers, and the SAM-D fire section is to have 20 (There are two fire sections per SAM-D battery) In an intense and prolonged air battle, such as the one over North Vietnam during December 1972, both systems could be forced to expend their ready missiles rapidly An Improved HAWK battery could reload its launchers in about minutes, using the additional ready missiles The Army requires that each SAM-D launcher be reloaded in minutes, thus it would take for the one crane to reload the five launchers in the SAM-D fire section.

The Army is examining the method of reloading the SAM-D launchers, the personnel and type of equipment needed, and the means of transporting the missiles from storage to the

launchers It is considering resupplying the fire units with missiles on additional ready launchers According to the September 30, 1972, Selected Acquisition Report, a launcher without missiles costs about .

Although the SAM-D system and the Improved HAWK are radiating energy, they may be attacked by antiradiation missiles (ARMs) which seek to home on this energy (See fig 5, below) The Sam-D radar signature is stronger than the Improved HAWK's because of its higher power level and therefore may be more susceptible to attacks On the other hand, the SAM-D radar may have a better chance to defeat these ARMs because of its inherent design features and because of its greater range capability during the first attack wave (See p 39 of study to counter ARMs) But the Improved HAWK may have a better chance against succeeding waves because it has two acquisition radars

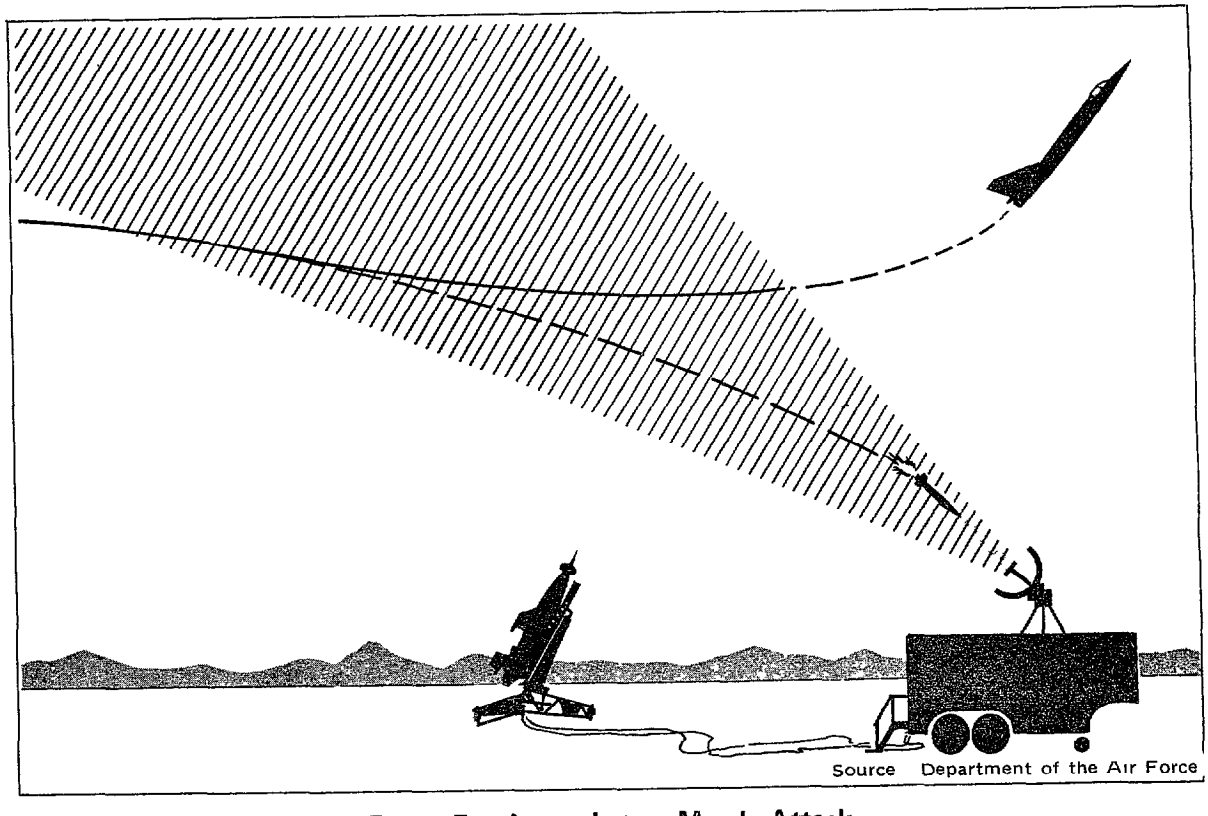


Figure 5 – Antiradiation Missile Attack

The Improved HAWK and the SAM-D system both have "dead" zones, that is, airspace close to the unit in which missiles cannot be adequately controlled nor targets tracked to intercept Enemy aircraft may enter this dead zone through low-altitude terrain-masking flights According to the Army, the grouped fire sections will cover each other's dead zone Since these fire sections are planned to be deployed about miles apart, the attacking aircraft might come in below the radar horizon of the adjacent fire section

ECM

It is expected that a sophisticated enemy would employ many kinds of electronic devices to jam or mislead our surveillance, communication, navigation, and weapon-aiming devices An important justification for the SAM-D program is increased capability or immunity in a dense electronic environment

Despite the high enemy-jamming power levels, both the Improved HAWK and the SAM-D system achieved in the simulation sizable attrition rates against enemy aircraft which led the Army to conclude that either defense system is adequate to meet the anticipated threat if deployed in sufficient numbers

---

[1]The simultaneous obstruction of the frequency band used by AD radars so that the radar reflections from the targets (e g , enemy aircraft) are drowned in static noise

Self-screening jammers, that is countermeasures on board the enemy aircraft, were used in the simulation against the SAM-D system but not against the Improved HAWK ADEB stated

> "The capability of this system (Improved HAWK) precludes the use of SSJ [self-screening jamming] Therefore, only SOJ [standoff jamming] was employed * * * "[1]

The SAM-D system is intended to have the capability to

Manpower and maintenance requirements

The Army is planning for fewer personnel for the SAM-D system than for the currently deployed force of the Improved HAWK and Nike Hercules systems The DCP repeats the smaller manpower estimate but states

> "Replenishment spares and maintenance and overhead costs of the SAM-D mission equipment will cause operating costs per battery to be greater than Improved HAWK, offsetting the cost advantage of fewer personnel."[2]

The DCP shows that 7,500 fewer people would be needed worldwide on the basis of the assumption that, in SAM-D batteries will replace Improved HAWK and Nike Hercules batteries There would be an additional life-cycle cost increment of $2 2 billion for the field army in spite of the fewer personnel programed for Using the Army's estimates, the

---

[1]Secret report by the USACDC, Air Defense Evaluation (1980-1990) (U), Task 5 - Evaluation of Alternative Air Defense Families, Vol VI, Annex E, Apps VII and VIII (Fort Belvoir, Va USACDC, Nov 1970), p. E-VIII-d-6

[2]Secret report by the Director of Defense Research and Engineering (DDR&E), Surface-to-Air Missile Development (SAM-D) Development Concept Paper No. 50 (Washington DDR&E, March 13, 1972) p. 8

DCP estimates the 10-year life-cycle cost at $102 million for a SAM-D battery compared to $43 million for an Improved HAWK The DCP referred to the ADEB study which stated that the Improved HAWK deployment would have to be with associated increase in cost and personnel to provide adequate defense from 1980 to 1990

The Army plans to allocate an average of 95 people to each SAM-D fire section, which will include eight trained as system maintenance personnel (The missile itself is expected to be a maintenance-free certified round)

Table 1

Summary of Comparative Data
on Improved HAWK and SAM D Systems

	Improved HAWK battery	SAM D fire section (note a)
Acquisition coverage		
Maximum range (miles)		
Azimuth (degrees)	[b]360	
Tracking coverage		
Maximum range (miles)		
Azimuth (degrees)	[b]360	
Simultaneous targets tracked		
Dead zone (miles) (note c)		
Guidance number of missiles simultaneously	2	
Maximum intercept altitude (ft)		
Maximum intercept range (miles)		
Reaction time (secs) (note d)		
Missile on launchers	18 (TRIAD 27)	20
Launcher reload time (mins)		
March order/emplacement time (mins) (note e)		
Electromagnetic pulse hardening	no	[b]yes

[a]Two fire sections per battery

[b]Indicates superior capability

[c]Air space around the unit in which missiles cannot be adequately controlled nor targets tracked to intercept

[d]Time from target detection to missile ignition

[e]Time to go from operational status to road march and time from arrival on site to reach operational status respectively

CHAPTER 3

ASSESSMENT OF CRITICAL MANAGEMENT ACTIONS

Numerous management actions are required during the acquisition cycle of a weapon system In this chapter, several of the more critical actions are described, followed by a discussion of how DOD applied each of these actions before approving the SAM-D system for engineering development

CRITERIA

According to DOD Directive 5000 1, dated July 13, 1971, at the time a weapon system is to enter the engineering-development phase

> "* * * the DSARC will normally review program progress and suitability to enter this phase * * * Such review will confirm (a) the need for the selected defense system in consideration of threat, system alternatives, special logistics needs, estimates of development costs, preliminary estimates of life cycle costs and potential benefits, in concept with overall DOD strategy and fiscal guidance, (b) that development risks have been identified and solutions are in hand, and (c) realism of the plan for full-scale development "

During the acquisition process, the continued need for a specific capability must be revalidated at regular intervals, performance characteristics must be redefined, the feasibility of achieving the performance characteristic must be reassessed, and a determination must be made that the weapon system is still the most cost-effective alternative

Army review

In 1970 the Army established ADEB to review the capabilities of the Army's AD systems and to develop information to help higher authorities decide on improvements to

existing short-range systems and whether the engineering development of the SAM-D system should begin ADEB covered the air-breathing threat (e g , aircraft) weapon systems performance, cost effectiveness, and technical risks associated with the SAM-D program

According to the Army, the ADEB report is the current authoritative source revalidating the need for the SAM-D system We reviewed the ADEB report which was approved by the Army's Chief of Staff We also reviewed actions taken by the Army and DOD since the ADEB study On the basis of our review, we are presenting certain aspects of the study and recent events which raise issues about the management actions affecting the SAM-D program.

In its review, ADEB found that the Army lacked an adequate, continuing program of study and analysis on which to base sound decisions on AD development ADEB recommended that such a program be established to pick up where the ADEB left off

> "* * * capitalizing to the extent resources will allow on the personnel, data and techniques assembled for the ADEB effort Significant problem areas that should be addressed by such a continuing study program are

With regard to the ADEB recommendations, Army-sponsored studies on SAM-D's ECM susceptability are underway, an army field area coordinating paper is being developed, and a forward area AD study is being made

In February 1972 DSARC reviewed the SAM-D program and, on the basis of the ADEB study and other considerations, DSARC recommended to the Deputy Secretary of Defense that the SAM-D system be approved to enter engineering development. Engineering development formally began in March 1972 with the award of a $563 million contract

Threat study

An analysis of the currently postulated threat is needed to revalidate the need for a weapon system.

ADEB prepared a detailed threat study which outlined the character of the threat against which SAM-D was to defend It reviewed approved threat data from DIA and the Office of the Assistant Chief of Staff for Intelligence of the Army DIA's approved threat data, however, projected the threat only to , short of the SAM-D system's

---

[1] ADEB Summary, p 39

operational period of In addition, in ADEB's view, the approved threat was oriented toward nuclear conflict, but ADEB was to address the SAM-D system in nonnuclear warfare In the absence of hard data, ADEB extrapolated the data at hand in the development of the nonnuclear 1980-95 threat.

ADEB projected a threat which was most likely to be posed by the Warsaw Pact[1] against the 7th Army and which was representative of the worldwide threat to the field army ADEB did not address the specific threat against which the additional SAM-D systems planned for deployment in Alaska, the Pacific, and CONUS would be expected to counter

In postulating the threat to the 7th Army, ADEB assumed, in its scenario, a buildup of U.S ground forces in Europe to divisions by 1979 and a responding Warsaw Pact increase in the number of tactical aircraft by 1979

The total number of Soviet aircraft postulated for the 1979 ADEB scenario was from

[1] An alliance of eastern European nations similar to NATO The Soviet Union is the leader of the pact

Table 2

Total Soviet Aircraft Threat

	1970 ADEB scenario estimate for 1979 threat	1970 DIA estimate for 1979 threat	1972 DIA estimate for 1981 threat
Fighters-interceptors			
Fishbed C/D/E/F/H (MIG-21)			
Fitter A/B (SU-7)			
Flogger (MIG-?)			
Total fighters-interceptors			
Bombers and reconnaissance			
Tactical			
Brewer B/C (YAK-27/28R)			
Mangrove, Brewer D (YAK-27/27R), Fishbed			
Total tactical bomber and reconnaissance aircraft			
Future models			
Foxbat (MIG-25)			
Advanced VG fighter			
Advanced tactical fighter			
TF STOL (tactical fighter--short takeoff or landing)			
Total future models			
Long-range aviation units			
Badger (TU-16)			
Blinder (TU-22)			
New bomber (Backfire)			
Total medium bombers in long-range aviation			
Total aircraft			

The Army assumes that future models have two to six times more damage capability than do current models In establishing the requirement for the SAM-D system in the rear area, ADEB also considered many more

Definition of performance characteristics

Determination of weapon system performance characteristics, such as speed, range, and accuracy, depends on well-defined statements of the objectives and tasks required of the potential system These characteristics are used to circumscribe trade-off studies and performance feasibility studies Performance specifications developed from these characteristics define initial design feasibility studies and validation efforts Absence of well-defined specifications can cause underdesign or overdesign of a system

Changes in SAM-D system characteristics

There have been substantial changes since 1965 in design and performance characteristics of the SAM-D system (See table 3, p 37) For example, some of the data for 1965 and 1969 reflects a design capability for defeating targets of high speeds and altitudes, such as . The current SAM-D system has been reoriented to reflect a primary capability against more maneuverable air-breathing targets and,

Table 3

Changes in Characteristics

Item	1965 concept formulation	March 1969 DCP	Current system
Target type	Prime threat consisted of nonmaneuvering target at long range	Same as 1965	
ECM threat		Same	
Target size (note a)		Same	
Number of launchers in fire section	2	[b]3	5
Number of missiles on each launcher	5	6	4
Mounting of the equipment fire control group (note c)	Single vehicle (tracked)	Same	3 vehicles (wheeled)
Sector coverage	360° (4 fire sections)	Same	(1 fire section)
Radar power			
Missile			
Airframe	Winged	Wingless	Wingless
Warhead	Nuclear or conventional	Same	Nuclear option
Warhead design			

[a]Radar reflection size of target

[b]Source Technical Development Plan

[c]Includes radar prime power and weapons control

ADEB reviewed the Army's 1967 qualitative materiel requirement which showed the performance characteristics for the SAM-D system against the air-supported threat and short-range ballistic missiles. ADEB did not address the ABM performance characteristics, however, because its charter was to revalidate the capabilities needed in the SAM-D system against the air-supported threat. ADEB concluded that, with few exceptions, the performance characteristics contained in the qualitative materiel requirement would provide an austere design against the air-supported threat. ADEB cited, as exceptions, the nuclear warhead, radar power level, and control computer memory and software. ADEB recommended revisions to the qualitative materiel requirement which deleted the minimum performance characteristics against but which retained a SAM-D design which

would give the Army the option of adding a nuclear warhead
. (This revised
version of the SAM-D system became the basis for the 1970 qualitative materiel requirement.)

The September 1972 MN-ED which replaced the 1970 qualitative materiel requirement said

The document permitted including ancillary features to improve the SAM-D system's performance against
provided that these additions would not significantly affect cost or degrade performance against the air-breathing threat

The specifications in the SAM-D contract provide that the system have an capability derived from its capability against the air-breathing target when the system determines that the kill probability is acceptable, however, there are no plans to test it. Research and development and procurement funds for the nuclear warhead have been deleted from the program, however, the design and development of the ground support equipment and missile to retain the minimum essential features necessary to maintain a nuclear option will continue. The approved program for the SAM-D system calls for (1) a single-shot engagement kill probability of against a single target, (2) simultaneous engagement of targets, and (3) a maximum intercept altitude of feet. In addition, the SAM-D system is required to engage targets flying up to miles per hour.

ADEB concluded that, given sufficient deployment, both the Improved HAWK and the SAM-D system have the performance capabilities needed in a long-range system to provide adequate defense against the air-breathing threat

Potential changes to SAM-D system

DOD is conducting a number of studies to determine how the performance of the SAM-D system can be improved, particularly in those features which are recognized as having shortcomings.

1. Research is being performed by a contractor to determine the feasibility of providing the SAM-D system's radar with a 360° search and track capability.

2. Studies pertaining to the survival probability of the SAM-D system's radar when attacked by antiradiation missiles and a study of countermeasures are underway. (See p. 27 for further discussion of survival.)

3. A study to determine methods of expediting the reloading of the missile launchers is also underway.

Effectiveness to accomplish mission

ADEB's approach was to establish equal-effectiveness forces using the criterion of given limitations of damage to U S assets It was concluded that

> "Employed in sufficient numbers and in conjunction with improved short range air defense weapons, either the Improved HAWK or the ADEB SAM-D weapon system is capable of providing an adequate defense against the nonnuclear air-supported threat to the Army in the field "[1]

Examination of the methodology and specific results from the ADEB study indicates there is some question as to whether the final force level of the SAM-D system will be capable of adequately defending the field army

ADEB criteria established acceptable damage thresholds at percent for such assets as airbases, missile units, and AD units and at percent for signal centers, depots, and the like For convenience in comparing dissimilar targets, these thresholds were expressed as percents of the initial investment dollar The AD system was to be made sufficiently strong to hold the damage level to each target class at or below the threshold level over a 30-day operating period By use of descriptions of enemy aircraft, their ordnance loads, and the kill probabilities against various targets, ADEB developed a dollar value damage per sortie (reaching bomb release point) for each target class and from that, the number of sorties required to obtain -percent (or -percent) dollar damage against each target class. ADEB then used the results of the detailed simulation runs, Tactical AD Computer Simulation, to determine attrition rates to aircraft that would be used in the 30-day campaign model, (Deterministic Mix Evaluation Worldwide) This model would then operate the threat force over the 30-day period and compute the number of sorties, and consequently the dollar damage level, achieved against

---

[1] ADEB Summary, p 32

each of the target classes This model also included the effect of Blue Air Force (friendly) in causing attrition to Red aircraft (enemy)

Application of criteria

If the threshold was exceeded, the size of the AD family was to be increased until the damage level was held at, or below, the threshold After the first preliminary trials,

The next most damaged target was airbases, and it was this target class that determined the size of the family The dollar damage levels achieved by the initial trial families using the 30-day campaign model and by the final families are presented in the ADEB study. All other target classes, except air bases, had damage levels well under the threshold, but the damage levels to the AD systems are not shown in the model

With regard to deleting the -percent damage limit, the Army's position was that, for forces engaged directly in the mixed air battle, an alternative criterion to a threshold of damage was a favorable exchange ratio between offensive and defensive system losses, that is, the fractional damage to enemy aircraft would equal or exceed the fractional damage to friendly AD forces According to the Army, this is a satisfactory criterion if it means that the enemy's capability to inflict damage to other ground targets diminishes in direct proportion to its ability to defend those targets, and therefore, the Army retains its same capability to limit damage to friendly targets

Discussion

The following analyses address the survivability and effectiveness of the SAM-D system based on the ADEB scenario

and computer simulation results (Tactical AD Computer Simulation)

In -altitude attacks, the simulation results showed that percent of the SAM-D fire sections were killed and, in turn, percent of suppression aircraft were killed The quantity, fraction of fire units killed, should be the measure of vulnerability of the AD system This value was accomplished by aircraft sorties on the first raid Since this first raid represents only about percent of the effective sorties possible in a 30-day effort, it seems clear that the threshold damage to the AD family will be exceeded by a wide margin.

In altitude attacks, the simulation results showed that the SAM-D system is much more effective in attriting aircraft than at altitude and that SAM-D system losses are less than at altitude Nevertheless, the SAM-D system suffers a -percent attrition rate in altitude attacks With the force mixes and levels used in the simulation, the enemy would prefer to come in at altitude so that he would suffer considerably fewer overall losses In a attack, the systems are only marginally useful, the system, the SAM-D system, must do most of the work For altitude attacks, the SAM-D system kills more aircraft and is less vulnerable than is the case for altitude

This analysis compares the ability of the SAM-D system to adequately defend the field army against the criterion of -percent limitation of damage to AD units over a 30-day period The SAM-D system does not meet this criterion, but the high attrition rates obtained on enemy aircraft are a strong deterrent The results do not reflect the use of friendly air forces or operational and tactical procedures which could significantly change the results of the computer simulation The conclusion can be drawn, however, that AD suppression is a serious threat and that the means for improving the SAM-D system's survival need to be addressed during development

The Army concluded that the high attrition rates inflicted on the attacking aircraft were the overriding factors in determining AD system force levels and that the -percent damage limiting criteria for AD units was not a driving factor

Effectiveness results reported by ADEB. To determine if attrition to AD units was kept below threshold, an examination was made of the simulation. Key inputs and results are shown in table 4

Table 4

ADEB Tactical AD Computer Simulation Results (note a)

(SAM-D Family) (note b)

	SAM-D family	
	Medium-altitude	Low-altitude
Inputs		
Total aircraft attacking		
SAM-suppressor aircraft		
Number of aircraft carrying number of ARMs (aircraft/ARMs)		
Total SAM-D sites		
Results		
Number of aircraft killed		
Number of SAM-suppressor aircraft killed		
Number of SAM-D sites killed		
Analysis		
Total aircraft killed per SAM-D site killed		
Aircraft killed by SAM per SAM-D site killed		
SAM-suppressor aircraft killed, per SAM-D site killed		
Fraction SAM-suppressor aircraft killed		
Fraction of SAM-D sites killed		

[a]Simulation of first raid

[b]Improved short-range AD

Technical risk

Technical feasibility studies pinpoint high-risk areas Greater emphasis can then be given to minimizing these risks and to special testing used to monitor the planned progress Determining feasibility through testing also can be used to anticipate specific technical difficulties Testing is a valuable means of assessing subsystems and system design progress, it gives management information on which to base decisions, such as to continue as planned, to modify a design approach, or to discontinue the program Entering into full-scale development without testing design feasibility can result in attempts to achieve unrealistic technical progress.

New technology

The more critical areas of the SAM-D system are the radar, missile guidance, and boost-glide, wingless missile design.

The SAM-D system's radar is not to be the conventional rotating disc antenna, but a flat-plate, phased-array type. Such a plate consists of over 5,000 electronic antenna elements which are switched and phase-shifted by a high-speed digital computer to form the radar beam The radar is expected to emit power in discrete frequencies and to use various techniques to enable the system to operate in severe clutter and electronic countermeasures environments

The TVM guidance system is expected to home on multiple small and fast targets with better accuracy than the HAWK and Navy standard missile guidance systems. TVM guidance was planned for the Navy's Typhon system which was canceled in 1964 It was again considered, but rejected, for the Navy's Aegis missile system after being assessed as a high-risk element and not necessary for an antiaircraft weapon. The problems with TVM guidance concern (1) directing the missile's nose antenna at the target and the rear antenna at the ground radar and (2) the complex data and command links. (See p. 23 for further discussion on the guidance system.)

The SAM-D's missile is to be a boost-glide, wingless configuration with very high acceleration and speed After

rocket-motor burn-out, about seconds after launch, the missile would coast to the target, losing its speed if forced to maneuver. Other AD missiles, designed against aircraft and winged missiles, use lower speed, a sustainer motor, and wing surfaces to maneuver.

Technical assessment

ADEB assessed the technical risk of the SAM-D system to determine whether (1) the system will achieve the performance objectives for which it is being designed or (2) serious technical problems might emerge during development which would require additional cost and delay ADEB concluded that the development program does not appear to present any major problem that might prevent success or cause a major increase in cost The contractor has conducted limited tests through simulations and development hardware and is convinced that the design and performance goals can be achieved

In June 1970 free flight-testing of the TVM guidance concept was postponed to engineering development, currently in 1974 Waiver of the flight-testing was granted by DDR&E, who based his action on the fact that delays had occurred in the program plan due principally to funding shortages These delays resulted in a less mature design model available for testing It was felt by DDR&E that testing of this model would have significantly increased the costs of the tests and decreased the benefits to be gained over that previously envisioned

The Army estimated these cost increases to be over $35 million The flights during advanced development were to provide an early demonstration of the guidance capabilities The Army relied on captive flight tests and simulations, instead of the actual live tests, to prove the guidance system.

The Army says that the captive flight tests and simulations insured that the guidance component would function properly By the time the system's capability is demonstrated through the missile flight tests in September 1974, the Army will have spent about $793 million on the program. Deleting test vehicle flights from advanced development

also affected the implementation of other planned tests, such as electronic interference and warhead fuzing.

OTHER MANAGEMENT ACTIONS

ECM study

The Army is currently studying the SAM-D system's effectiveness in a combined electronic and tactical countermeasures environment

Requirements-Control Board

In 1972 the Army established the SAM-D Requirements-Control Board composed of senior military and secretariat personnel to review changes in requirements, specifications, or designs which may be recommended by the prime contractor and the SAM-D project manager The objective of this review is to aid in holding down development and production costs

System engineering cost reduction assistance contractor

Because of DOD's concern about the SAM-D system's high cost, the Army was directed to award a contract to International Business Machines Corporation in May 1972 to provide systems engineering cost reduction assistance Basically, the objective of this contract is to evaluate the progress of the SAM-D contractor, particularly in features where design influences the production costs It is anticipated that the corporation will aid the SAM-D project manager in identifying and recommending means for reducing production hardware costs.

Area coordinating paper

DDR&E is currently developing an area coordinating paper on AD. The paper will emphasize the threat to the 7th Army and the capabilities and/or deficiencies of current and proposed AD systems These systems are being reviewed to determine an integrated overall AD system by exposing gaps in the present coverage and by identifying development programs with high payoffs

CHAPTER 4

GENERAL OBSERVATIONS

The SAM-D program exhibits many of the characteristics identifiable with problematic weapon systems in the past Our review showed that the Army's assessment of the threat in terms of quantity and quality was greater than that determined by DIA Some performance capabilities were not well defined , and critical subsystems were not tested adequately in advanced development Therefore, DOD did not adequately apply the criteria established in its own directives in approving the SAM-D system for engineering development

CHANGING THREAT CAPABILITY DRIVES PERFORMANCE DEMANDS

In the genesis of the SAM-D system, the early primary threat was considered to be Later the two prime threats became and an type aircraft The primary threat subsequently became various tactical aircraft, but the SAM-D system would have a fallout capability against

The Army said that some capability was inherent in the present design Additional software development and an improved conventional or nuclear warhead section would be required to take full advantage of the SAM-D system's potential against The penalties in performance against the primary air-supported threat and the additional complexity and cost associated with the capability were not identified

ENLARGED THREAT ASSESSMENT

The airborne threat to be countered by the SAM-D system was shown to be greater by the ADEB study than by the comparable DIA estimates, primarily because the ADEB nonnuclear simulation postulated (1)

forces in a buildup to divisions in Europe by 1979 and (2) a responding increase in Soviet deployed aircraft Then too, the study posited advanced aircraft with greater capability than DIA predicted The ADEB assessment of the threat enhanced the expected worth of the SAM-D system and led to large defense force requirements for the Improved HAWK

EFFECTIVENESS ANALYSIS

The ADEB study of tactical AD requirements concluded "that either the Improved HAWK or the ADEB SAM-D weapon system is capable of providing an adequate defense" but that, for a sufficient deployment of either system, life-cycle cost of the SAM-D system would be 30 percent of the life-cycle cost of the Improved HAWK system The ADEB numbers showed the cost of the SAM-D AD family to be 61 percent of the cost of the equally adequate Improved HAWK family

The Army's cost-effectiveness study used fractional dollar damage levels to various field army assets received in a 30-day period as the threshold criteria for developing an effective SAM-D AD system. These assets, among other components, included airbases, surface-to-surface missile units, and AD units We found that the size of the "adequate" SAM-D system was determined by limiting airbase damage to percent, the threshold criteria However, damage to the surface-to-surface missile units and the SAM-D system exceeded the percent criteria set for them The ADEB report states that it was determined that

Vulnerability of an AD system can be measured by the fraction of force that survives The SAM-D system loses percent of its units at altitude At altitude, SAM-D's best operating regime, it loses percent These loss rates were obtained during the first raid Extended over a 30-day period, the losses should be substantially greater

The Army concluded that the very high attrition rates (about percent) inflicted on the suppression aircraft were the overriding consideration in determining AD system force levels and that the percent damage limiting criteria for AD units was not a driving factor.

TECHNICAL UNCERTAINTIES

Although major weapon systems are not to be moved into engineering development until technical uncertainties are resolved, the potentially problematic TVM guidance system, which has no operational precedent, was never flight tested and the critical warhead-fuzing interface will not begin flight-testing until 1974

Although testing of the guidance system through actual missile flight would have cost an estimated $35 million, such tests would have minimized associated risks during engineering development Fuzing problems have plagued other missile programs, and the much faster SAM-D missile will require much quicker fuze sensing

Other uncertainties are yet to be resolved Studies are continuing, for example, to determine how to provide the SAM-D system with 360° radar coverage, ways to devise counter-countermeasures against antiradiation missiles, and means of quicker reloading of missile launchers

Decisions to forego testing during advanced development have often resulted in substantially increased costs and lower performance accomplishments

HIGHER COST, FEWER UNITS

Since the Army's 1967 development estimate, the costs and quantities of the total program have changed from $4,031 million (computed in constant 1967 dollars) for tactical fire sections to the current estimate of $4,377 million for tactical fire sections (approximately program unit cost for each fire section)

JUSTIFICATION OF PROCUREMENT QUANTITIES

The ADEB study found SAM-D system fire sections adequate for the defense of the 7th Army area Extrapolating directly from the division European case, ADEB stated a requirement of fire sections for a worldwide Army force level of 21-1/3 divisions Although future force structures are uncertain, 13 active and 8 reserve divisions are presently authorized

There are fire sections presently planned for Europe, are programed for tactical units in CONUS, for the Pacific, and for Alaska Another fire sections are planned for strategic defense of CONUS for a total of

JUSTIFICATION OF THE SAM-D CONCEPT

The Army believes that better performance in an intense electronic-warfare environment, multiple-attack capability, and potential manpower savings are the superior attributes of the SAM-D system

Resistance to ECM

Both the Improved HAWK and the SAM-D systems are justified for their superior capability in an intense ECM environment In this environment used by ADEB, the Army concluded that either the Improved HAWK or the SAM-D system would be adequate to counter the anticipated threat when deployed in sufficient numbers

Multiple engagement capability

Aircraft attacks are flown in waves, spaced by several minutes between flights, for total attack durations of minutes

Although the SAM-D system can fire its basic load of missiles faster than the Improved HAWK, to provide a high attrition of enemy aircraft over short periods, the Improved HAWK has a sustained firing capability, because of

fast reloading of missiles on launchers For example, during a 30-minute attack period, HAWK could fire as many as missiles, or even missiles, in the triangular AD configuration, while the SAM-D system battery would be limited to firing its 40 missiles before reloading Because of the prolonged time required to reload the launchers, DOD officials have acknowledged the SAM-D system will be vulnerable to follow-on enemy attack The Army SAM-D project manager informed us that the Army was aware of this deficiency and that studies were underway to determine the cost of either faster reloading or additional launchers

Manpower and operating requirements

The statement of reduced personnel requirements for the SAM-D system was based upon the assumption made in DCP that SAM-D system batteries would replace Improved HAWK and Hercules batteries by , leading to a worldwide savings of 7,500 personnel DCP referred to the ADEB results which stated that the HAWK deployment would have to be to provide AD in 1980 to 1990.

DCP estimates more spares, maintenance, and operating costs for the SAM-D system than for the Improved HAWK it is to replace Fewer personnel are estimated, however, because of less maintenance A number of the maintenance concepts have not been proven in real life, and it remains to be demonstrated that these predicted reductions will become reality The Army is confident, with present technology and increases in reliability of recently developed components, that these reductions in personnel are reasonably attainable

DCP manpower estimates are currently under revision, present Army plans anticipate even larger reductions in personnel with deployment of the SAM-D system

MISSION AND NATURE OF THE FIELD ARMY AD

The priority assets to be protected by the 7th U S Army (Europe) are surface-to-surface missile sites, troop concentrations, artillery batteries, Army aviation, AD fire units, command and control centers, signal installations, supply depots, maintenance and repair units, Rhine River bridges, rail centers, main supply routes, and U S Air Force bases [1] The several Air Force bases in the 7th Army's area play an essential role in the land battle and, therefore, are a prime 7th Army concern

Not only must the 7th Army defend its resources from invading ground forces, but, together with U S and Allied air forces, it must protect from enemy air forces with an effective AD network (The tactical AD mission, over land, is a joint one shared by the Air Force and Army, however, in the 7th Army, theater AD assets are controlled by the Deputy Air Force Commander.) According to the Army, its currently deployed long-range AD systems--Nike Hercules and the Improved HAWK--will not provide the most cost-effective capabilities needed for 1980 and beyond against the threat posed by the tactical air forces of the Warsaw Pact nations

THREAT DATA

DIA has had overall responsibility for coordinating and evaluating intelligence data for DOD According to DIA, the

Presented in table 2 (p. 35) are data on Soviet aircraft projected by DIA to be the tactical aviation by 1979 [2]

---

[1]ADEB Summary, p 28.

[2]Top Secret report by DIA, Defense Intelligence Projection for Planning (DIPP) (U), Section IV (Washington, D C DIA, 1972), p. IV C-7.

APPENDIX I

Presented below are general comments contained in DIA sources about the character of the Warsaw Pact's tactical aircraft, weapons, and ECMs.

Threat aircraft

Principal aircraft threats dictating SAM-D's design

The Army's MN-ED[1] lists five aircraft as dictating design characteristics for the SAM-D

---

[1]MN-ED, p 2

[2]Flying at low altitude to approach its target, to deliver its ordnance, and to return to home base.

[1]Represents a force eight times the weight of an object.

APPENDIX I

Air-to-ground missiles

Electronic warfare

[1]Secret report by DDR&E Surface-to-Air-Missile Development (SAM-D) Development Concept Paper No. 50 (Washington DDR&E, Mar 13, 1972), p. 3.

THE AD ENVIRONMENT

In the event of war in Europe, the Army expects the Warsaw Pact nations to deploy some of its tactical air weapons against 7th Army assets, using a variety of attack modes The outcome of the air battle would be affected by the quality and quantity of weapons deployed by both sides, including the capability of the weapons to operate effectively in an intense electronic warfare environment.

Electronic warfare involves measures to prevent or reduce the effectiveness of opponent equipment employing or affected by electromagnetic radiations and to exploit the opponent's use of such radiation (ECM) For example, the Army expects the Warsaw Pact to employ sophisticated ECM equipment against defending radars so as to prevent the radars from targeting Warsaw Pact aircraft On the other hand, AD systems' radars, missiles communication, etc , must employ electronic counter-countermeasures to overcome the Warsaw Pact aircraft's deceptive and other electronic warfare practices.

A variety of tactics are available to the Warsaw Pact to penetrate friendly airspace. The Warsaw Pact attackers may use

The Army expects the Warsaw Pact to have

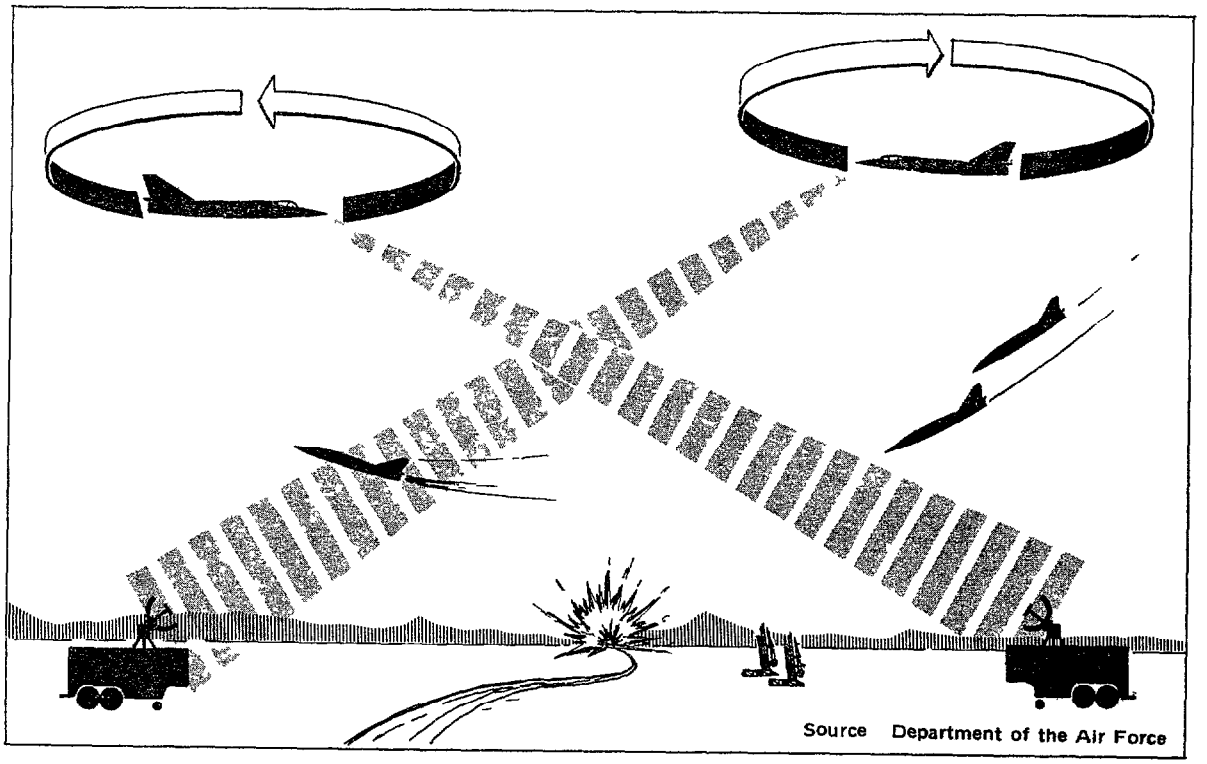


Figure 6 – Stand-Off Jamming Support

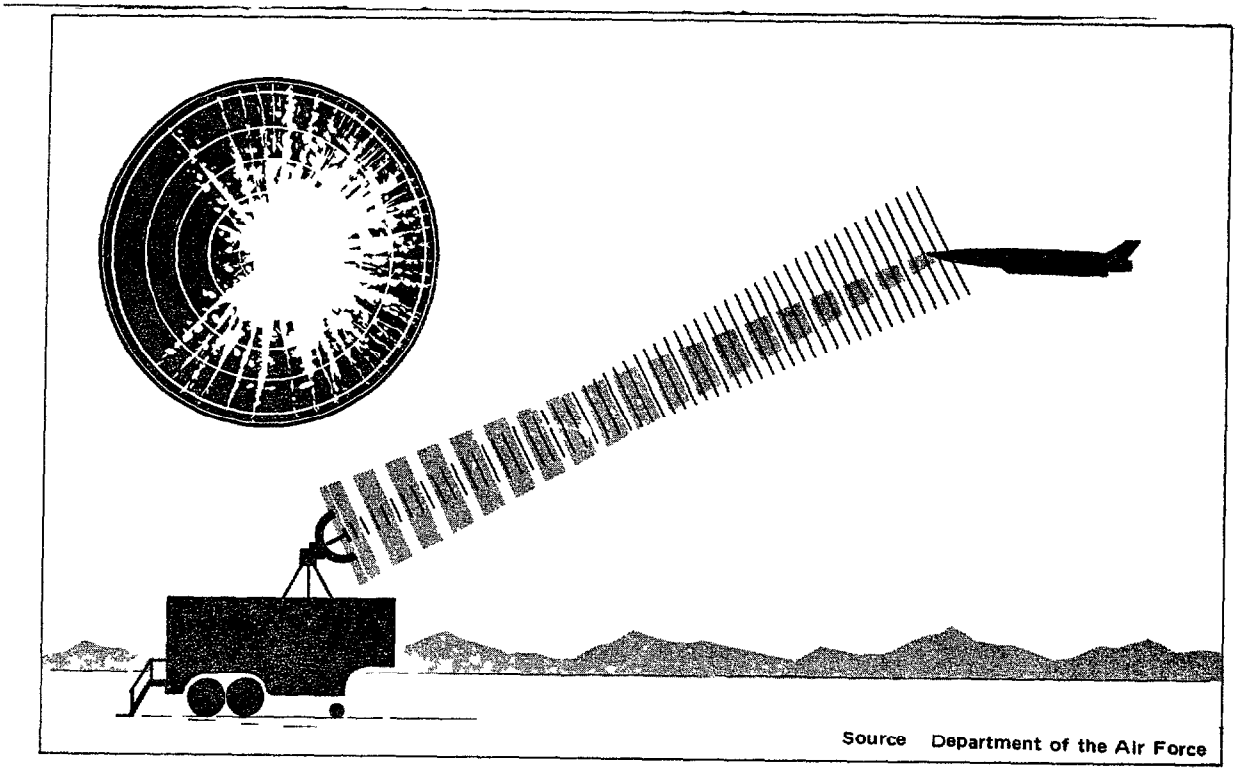


Figure 7 – Radar Scope Interference from Self-Screening Jammer

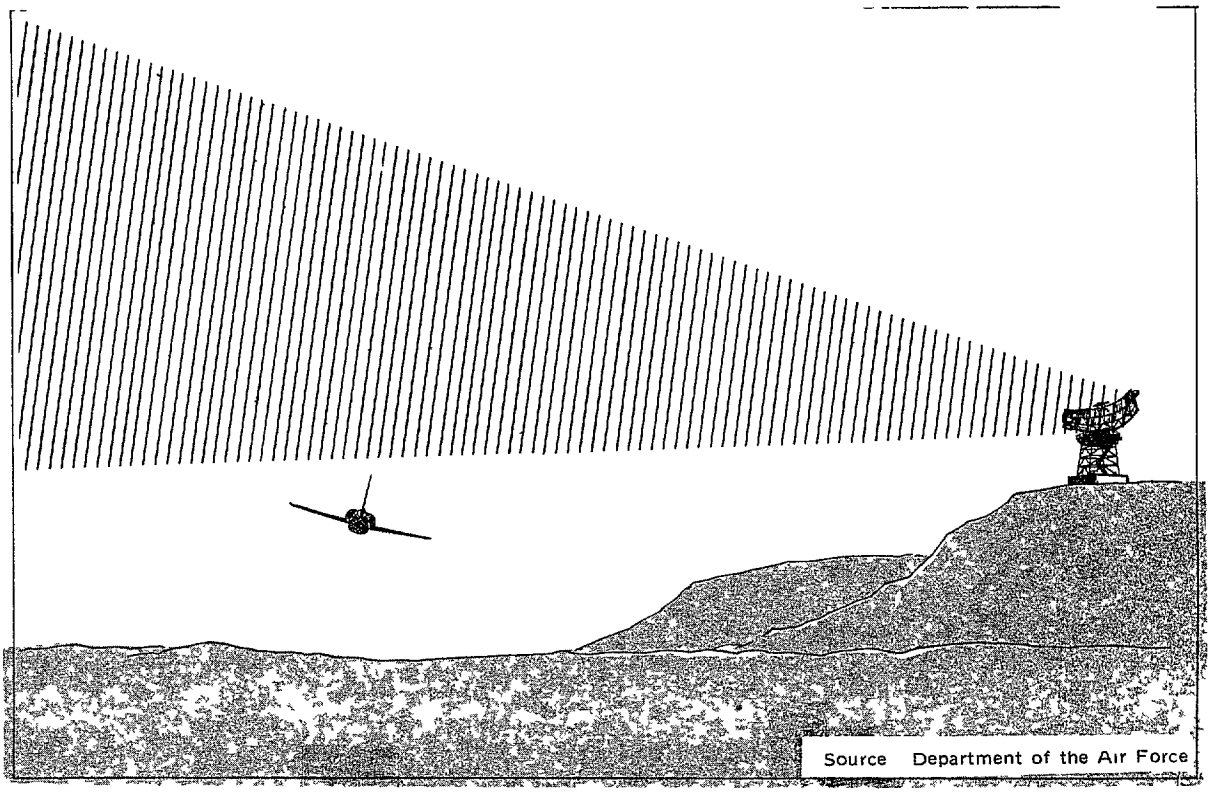


Figure 8 – Low Level Evasion

The 7th Army assets, such as troop units (infantry, armor, etc) and artillery units, are located in the forward area (closest to the enemy) Airbases, supply depots, command and control installations, etc , are well to the rear Although the AD weapons defending these assets protect the entire area, some types are best suited for rear-area defense, some for forward-area defense, and others are more or less suited to defend throughout

Rear-area weapons

The 7th Army currently deploys the Nike Hercules and the Basic HAWK missile systems and is also beginning to deploy the Improved HAWK coming out of production to replace the Basic HAWK These weapons provide large-area and vital-area defense against aircraft penetrating at low to high altitudes Aircraft taking advantage of terrain masking can usually escape detection by defense radars, but they can be visually acquired (See fig 8 above)

Nike Hercules

The Nike Hercules is an all-weather, radar-command guided system It can engage targets flying at speeds over miles per hour at ranges out to miles and at altitudes up to feet According to the Army, the Nike Hercules has limitations which would make it not acceptably cost effective in 1980 to 1990 The limitations noted by the Army are its

Improved HAWK

The Improved HAWK is the newest addition to the 7th Army's AD force It was discussed in chapter 2, along with the Army's proposed SAM-D system (replacement for Nike Hercules and Improved HAWK) being developed for use in 1980 to 1990.

Forward-area weapons

The 7th Army currently deploys short-range guns and missiles in forward combat areas to complement rear-area weapons. Forward-area weapons are used to protect assets in the immediate combat zone from low-altitude attackers giving little or no early warning These short-range systems are also used as last-resort weapons in rear areas, interspersed among aircraft shelters, for example

The Army has development, test, and evaluation underway to improve the effectiveness of forward-area AD systems

Manned interceptors

The Air Force has the F-15 aircraft in production to replace the F-4 as its primary air-superiority fighter The Air Force is also prototyping a lightweight fighter which would contribute to the AD mission The Navy's F-14

fighter, also in production, could be used when feasible, to supplement Air Force and Army defenses These aircraft would be capable of intercepting Warsaw Pact aircraft at low to high altitudes anywhere over the 7th Army area Although they are expected to be outnumbered by enemy fighter aircraft, U S aircraft have longer ranges and larger payloads

A major problem in the U S AD network is avoiding destruction of friendly aircraft by friendly, ground-based weapons Current forward-area AD weapons, unlike rear-area ones, have to confirm the aircraft identification visually

COMMITTEES:
ARMED SERVICES
CHAIRMAN SUBCOMMITTEE ON RESEARCH AND DEVELOPMENT
SUBCOMMITTEE ON PREPAREDNESS INVESTIGATION
SUBCOMMITTEE ON STATUS OF FORCES
SUBCOMMITTEE ON GENERAL LEGISLATION
SUBCOMMITTEE ON DRUG ABUSE IN THE MILITARY
SUBCOMMITTEE ON VOLUNTEER ARMED FORCE AND SELECTIVE SERVICE
SPECIAL SUBCOMMITTEE ON CLOSE AIR SUPPORT
SPECIAL SUBCOMMITTEE TO REVIEW BOMBER DEFENSE
BANKING HOUSING AND URBAN AFFAIRS
CHAIRMAN SUBCOMMITTEE ON SMALL BUSINESS
SUBCOMMITTEE ON HOUSING AND URBAN AFFAIRS
SUBCOMMITTEE ON FINANCIAL INSTITUTIONS
SUBCOMMITTEE ON SECURITIES
SUBCOMMITTEE ON PRODUCTION AND STABILIZATION
SELECT COMMITTEE ON SMALL BUSINESS
CHAIRMAN SUBCOMMITTEE ON GOVERNMENT REGULATION
SUBCOMMITTEE ON MONOPOLY
SUBCOMMITTEE ON FINANCING AND INVESTMENT

United States Senate
WASHINGTON D C 20510

THOMAS J McINTYRE
NEW HAMPSHIRE

OFFICES
SENATE OFFICE BUILDING
202 225-2841
FEDERAL BUILDING MANCHESTER N H
603-669-1232
FEDERAL BUILDING PORTSMOUTH N H
603-436-7720

September 1, 1972

Honorable Elmer B Staats
Comptroller General of the United States
Government Accounting Office
Washington, D C

Dear Mr Staats

1 The SAM-D system has been a program of special concern to this committee and became a subject of a floor amendment to delete the total funds requested in the FY 1973 Military Procurement bill During the debate on this amendment (Congressional Record of July31, 1972, pages S 12278-88 and S 12320-27) the amendment was withdrawn with the understanding that the committee would conduct a comprehensive review of the program and hold special hearings during consideration of the FY 1974 request

2 I understand that GAO has been conducting a study of the needs and capabilities of the tactical air defense mission since February 1972, with particular emphasis on the SAM-D program

3 Since the GAO study is covering major aspects of the SAM-D program, as well as the relationship to other long range tactical air defense systems such as interceptors and the HERCULES and Improved HAWK, the results of this study would be of substantial value as a basis for committee consideration of this program

4 Because the engineering development contract was awarded as recently as March 1972, the committee desires that any changes in requirements, specifications, or other elements of the program which are determined to be needed as the result of the reviews being conducted by GAO, the Army, the prime contractor and the Department of Defense be brought to the attention of cognizant officials in an expeditious manner to preclude added costs and further delay in the program In addition, you are requested to accelerate your efforts to complete your investigation and publication of a draft report which currently is planned for November, 1972 Moreover, as your study progresses, any urgent findings which are considered to be of sufficient importance should be brought to the attention of the Department of Defense promptly, so that they may be considered as the basis for actions before

completion of the study

5 The committee is concerned about certain aspects of this program which should be considered to the extent possible without delaying completion of the study These include, but should not be limited to, the following

a Interest of NATO countries in SAM-D or other systems identified with this mission requirement

b SAM-D requirements relating to range, altitude, multi-target capability, single phased array radar, degree of sophistication, complexity, EMP hardening, and ECM capability

c Growth potential of Improved HAWK

d Use and relationship of Aegis system with standard missile

e Projected enemy threat

f Utility of F-15 and other weapon systems for defense of the field Army and other high value targets

g Feasibility of deleting nuclear capability from the presently approved program

6 The committee is interested in obtaining copies of the draft report and all correspondence between GAO, the Department of Defense and contractor relating to this study It is also requested that a copy of the final report be provided no later than March 15, 1973, to provide a basis for committee action

7 The committee staff is conducting informal discussions with representatives of OSD, Army, and the contractor and this will continue In this regard, close cooperation between the committee staff and your staff would be constructive, and should include an interchange of information to avoid unnecessary duplication of effort

8 It is presently planned that formal hearings will be conducted approximately April 1, 1973, at which time representatives of your agency may be expected to appear and testify before the committee

8 A draft of this letter was reviewed and discussed in a meeting between Mr Hyman Fine of the staff of this committee, Mr Harold H Rubin, Deputy Director, and Mr Timothy D Desmond

Honorable Elmer B Staats September 1, 1972

of the Technology Advancement staff of your office on August 31, 1972

A copy of this letter is being sent directly to the Secretary of Defense to insure that all interested parties will be fully informed

Sincerely,

Thomas J McIntyre
Chairman, Subcommittee on
Research and Development

TJM Fm

SELECTED BIBLIOGRAPHY

Augustine, N K , "An R&D Perspective of Land Warfare" (U), Journal of Defense Research Series B. Tactical Warfare Arlington, Va , Institute for Defense Analyses, Fall 1971 (Classified)

Binny, A F , et al , Operational Effectiveness of SAM-D (U), McLean, Va , Research Analysis Corporation, February 1971 (Classified)

Comptroller General of the United States, Acquisition of Major Weapon Systems (B-163058) Washington, U S General Accounting Office, March 18, 1971 (Unclassified)

Defense Intelligence Agency, Defense Intelligence Projections for Planning (DIPP) (U), DE TSC 152H-72 Washington, Defense Intelligence Agency, March 14, 1972 (Classified)

Defense Nuclear Agency, DNA EMP Awareness Course Notes Chicago, IIT Research Institute, August 1971 (Unclassified)

Department of Defense, Acquisition of Major Weapon Systems, Department of Defense Directive 5000.1 Washington, Department of Defense, July 13, 1971 (Unclassified)

Director of Defense Research and Engineering, Surface-to-Air Missile Development (SAM-D) Development Concept Paper No 50 Washington, Directorate of Defense Research and Engineering, March 13, 1972 (Classified)

Mitchell, N E and Schilling, W R , Defense Against Tactical Ballistic Missile (U), McLean, Va , Research Analysis Corporation, June 1972 (Classified)

Monahan, R H , Analysis of the Relationship of Defense Tactical Mobility and Offense Reconnaissance and Strike Cycles to the Survivability of Army Air Defense (ADMAS) (U), Menlo Park, Calif , Stanford Research Institute, October 1969 (Classified)

U S Combat Developments Command, Air Defense Evaluation (1980-1990 (U), ADE 80 Fort Belvoir, Va , U S Army Combat Developments Command, November 1970 (Classified)

U S. Army Combat Developments Command, Materiel Need - Engineering Development (MN-ED) for Surface-to-Air Missile Development (SAM-D) (U), Fort Belvoir, Va , USACDC, September 18, 1972. (Classified)

U S Army Combat Developments Command, SAM-D Weapon Family Cost Effectiveness Study (U), Fort Belvoir, Va , U S Army Combat Developments Command, August 1967 (Classified)

AN EQUAL OPPORTUNITY EMPLOYER

UNITED STATES
GENERAL ACCOUNTING OFFICE
WASHINGTON, D C 20548

OFFICIAL BUSINESS
PENALTY FOR PRIVATE USE $300

POSTAGE AND FEES PAID
U S. GENERAL ACCOUNTING OFFICE

SPECIAL FOURTH-CLASS RATE
BOOK