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THE PATRIOT MISSILE SYSTEM:
A REVIEW AND ANALYSIS OF ITS
ACQUISITION PROCESS

by

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March, 1994

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This purpose of this thesis is to research the history of the Patriot weapon system, focusing on the acquisition strategy used in the Project Office, the evolution/upgrades of the weapon system, and the successes, failures, and lessons learned from Desert Shield/Desert Storm. An analysis is conducted to examine the effectiveness of the acquisition strategy in terms of cost, schedule, and performance, the ability of the Project Office to upgrade the system through the Patriot Advanced Capability Programs (PAC), and the performance of Patriot missiles against Scud missile attacks in Southwest Asia. This thesis concludes that the success of the Patriot project can be atributed to a combined evolutionary strategy and a Preplanned Product Improvement (P3I) approach, which allowed the Patriot system to evolve and counter a dynamic threat environment. The thesis offers a number of recommendations for application in future missile system projects.

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The Patriot Missile System: A Review and Analysis of Its Acquisition Process

by

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Submitted in partial fulfillment
of the requirements for the degree of

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ABSTRACT

The purpose of this thesis is to research the history of the Patriot weapon system, focusing on the acquisition strategy used in the project office, the evolution/upgrades of the weapon system, and the successes, failures, and lessons learned from Desert Shield/Desert Storm. An analysis is conducted to examine the effectiveness of the acquisition strategy in terms of cost, schedule, performance, the ability of the Project Office to upgrade the system through the Patriot Advanced Capability Programs (PAC), and the performance of Patriot missiles against Scud missile attacks in Southwest Asia. This thesis concludes that the success of the Patriot project can be attributed to a combined evolutionary strategy and a Preplanned Product Improvement (P3I) approach, which allowed the Patriot system to evolve and counter a dynamic threat environment. The thesis offers a number of recommendations for application in future missile system projects.

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I. INTRODUCTION

A. AREA OF RESEARCH

The area of research for this thesis is the acquisition strategy for the Patriot Air Defense Missile System. Specifically, this thesis will address what acquisition strategy was used in the Patriot project and how this strategy provided a means for improving the system's performance while minimizing risks in terms of costs and schedule delays.

B. RESEARCH QUESTIONS

The primary research question this thesis will answer is: How effective was the evolutionary acquisition strategy that served as the basis for the Patriot Air Defense Missile System's acquisition plan?

The following subsidiary research questions will also be addressed:

1. What are the elements of the evolutionary acquisition strategy used in the Patriot program?

2. To what extent was the preplanned product improvement (P3I) concept employed in the Patriot Missile Program and how effective was its use?

3. To what extent has the utilization of the lessons learned from Patriot's involvement in Desert Storm refined,

modified, or changed the acquisition strategy of the Patriot program?

4. To what extent can the acquisition strategy of Patriot be refined to improve its use and how might this strategy be used for future missile systems?

C. DISCUSSION

The Phased Array Tracking to Intercept of Target (Patriot) System was originally designed for the European theater to counter Soviet fixed-wing and rotary-wing aircraft. The system, originally known as the SAM-D (Surface-to-Air-Missile Development), replaced the Nike-Hercules missile system, which was one of the mainstays of U.S. air defense for more than 25 years.[1] Within the 32d Army Air Defense Command, Patriot firing units were typically deployed forward in a belt defense along the Inter-German Border and in the rear areas in defense of high value assets.

The development of the Patriot system was in response to various air defense studies conducted in the 1960's. The purpose of the studies was to examine the capability of existing air defense systems in countering the growth capability of threat aircraft.[2] These studies revealed that

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[1]"Nike Hercules Phased Out in CONUS", Air Defense Artillery Bulletin, March 1983, p. 1.

[2]Weiner, Ben W.K., and Leo C. Ramp, Jr., "The Army's First Patriot Battalion", Air Defense Magazine, April-June 1982, p. 35.

the Hawk and Nike Hercules HIMAD (High to Medium Air Defense) systems were inadequate and should be replaced by a newer system possessing the following attributes:

- High firepower.
- Resistance to electronic countermeasures.
- High kill capability against maneuving aircraft and aircraft in formation.
- Low manning requirements.
- Minimum logistics burden.
- High mobility and speedy emplacement.
- Growth potential to encounter increasing threat capabilities.[3]

The Patriot Air Defense system contains a number of inherent features designed to provide these capabilities. The initial design and production of the system incorporated the latest technologies available, such as a track-via-missile capability, consisting of a high speed, high maneuverable missile, and a multi-functioned phased array radar (AN/MPQ-53), which allowed the system to simultaneously track and engage multiple targets. Other features included a reduction in the amount of cabling, which significantly reduced the time required to emplace the system, and a launcher with four,

[3] Ibid.

fully self contained missile, which effectively eliminated the requirement for missile maintenance at the unit level (See Table 1-1).

TABLE 1-1 FEATURES OF THE PATRIOT SYSTEM

MODERN RADAR
- PHASED ARRAY ANTENNA WITH ELECTRONIC BEAM STEERING
- HIGH POWER/LARGE APERTURE
- ADAPTIVE ECCM
- ADVANCED SIGNAL PROCESSING

HIGH PERFORMANCE MISSILE
- HIGH SPEED
- HIGH MANEUVERABILITY
- ACCURATE ECM RESISTANT GUIDANCE
- LARGER WARHEAD
- PROXIMITY FUZING

FLEXIBLE INTEGRATED SYSTEM CONTROL
- HIGH SPEED, HIGH CAPACITY DIGITAL COMPUTER
- ADAPTABLE SOFTWARE CONTROL
- RADAR
- MISSILE GUIDANCE
- SYSTEM OPERATION

Source: Patriot Project Office Briefing, September 1993

During the early 1980's, the acquisition strategy for Patriot included the Patriot Advanced Capability Programs (PAC-1 and PAC-2), which emphasized increased lethality through software and hardware improvements. This capability, which was first fielded in 1989, was recently demonstrated during Desert Storm, where Patriot missile batteries successfully defended against Iraqi Scud missile attacks.

Current acquisition strategy includes a PAC-3 missile program, which is characterized as "...a combination of integrated complementary system improvements".[4]

At the present time, the Patriot system is considered the "...cornerstone of the theater army's integrated air defense."[5] With the increasing threat capability of tactical ballistic missiles, the only system currently in production with the ability to counter this threat is the Patriot PAC-2 missile. This thesis will examine the history of the Patriot weapon system, focusing on the acquisition strategy, the evolution and upgrades of the weapon system, the successes, failures, and lessons learned from Desert Storm, and the current and future trends for the Patriot Missile System.

D. SCOPE OF THE THESIS

The scope of the thesis will include the acquisition strategy of the Patriot, the roles and missions that Patriot was designed to handle, and an analysis of the problems and lessons learned from its deployment to Southwest Asia. This thesis also discusses unclassified system characteristics and capabilities.

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[4]Based on information contained in a Patriot Project Office briefing titled, "Patriot Growth Program Acquisition Overview", August 14, 1992.

[5]"MSD (Missile System Division) delivers 2,000 Patriot", The Missile Messenger, Aug 1988, p. 1.

E. METHODOLOGY

This thesis follows a case study format. The methodology involved two data types: interview data and the examination of articles, journals, periodicals, training manuals, and Patriot system documentation provided by the Patriot Project Office in Huntsville, Alabama. Research also included reports retrieved by means of an automated search for Patriot data available at the Defense Technology Information Center. Interviews were conducted with the Deputy Patriot Project Manager, the Assistant Project Manager, and various department managers within the project office. Thesis research travel to the Patriot Project Office occurred from September 13 to September 18, 1993.

F. BENEFITS OF THE THESIS

By examining the overall success of the Patriot Missile system, this thesis serves as a basis for future research and discussion on tailoring the right acquisition strategy for major weapon systems. A second objective is to consolidate various reports, documents, articles, and program manager perspectives into a single source reference for Patriot.

II. EVOLUTIONARY ACQUISITION STRATEGY

A. PURPOSE OF CHAPTER

An acquisition strategy provides a conceptual framework of the overall plan that a program manager follows in the execution of his program. Typical elements of an acquisition strategy include the contracting process, scheduling of essential elements, demonstration of test and evaluation criteria, solicitations for proposals, and several issues that address projecting life-cycle costs and the administration of contracting procedures. This chapter will examine the acquisition strategy employed during the initiation of the Patriot project, the concepts of evolutionary acquisition strategy and preplanned product improvement, and how the Patriot Project Manager employed these strategies in the execution of his program.

B. THE CONCEPT OF EVOLUTIONARY ACQUISITION STRATEGY

Evolutionary Acquisition Strategy is an approach that permits a system to be fielded and subsequently upgraded as new requirements and technologies are refined. Department of Defense Instruction 5000.2, Part 5, Section A, defines evolutionary acquisition strategy as:

...an approach in which a core capability is fielded, and the system design has a modular structure and provisions for future upgrades and changes as requirements are refined. An evolutionary acquisition strategy is well suited to high technology and software intensive programs where requirements beyond a core capability can generally, but not specifically, be defined.[6]

A preplanned product improvement strategy is defined as:

...a phased approach which incrementally satisfies operational requirements in order to address the cost, risk, or relative time urgency of different elements of the system being developed. With this approach, selected capabilities are deferred so that the system can be fielded while the deferred element is developed in a parallel or subsequent effort.[7]

The Patriot Project Office has incorporated aspects of both evolutionary and preplanned production improvement strategies in the acquisition of this system. The current acquisition approach describes Patriot as a missile system that is:

...modular in nature, characterized by high technology and is software intensive. The Patriot Growth Program is based on an evolutionary acquisition strategy and consists of a phased series of Preplanned Product Improvements (P3I) and enhancements derived from the Patriot Reliability, Availability, and Maintainability (RAM) Growth program. The adopted acquisition strategy provides a flexible, low-risk approach to improving system performance. Its primary goal is to minimize the time and cost of satisfying an identified, validated need consistent with common sense,

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[6]Under Secretary of Defense (Acquisition), Department of Defense Instruction Number 5000.2, Department of Defense, February 23, 1991, p. 5-A-5.

[7]Ibid.

sound business practices and the basic policies established by DoD Directive 5000.1, Defense Acquisition.[8]

C. HOW THIS STRATEGY WAS USED IN THE PATRIOT PROJECT

This section will track the acquisition strategy that was employed in the Patriot Project. It will also examine the significant events that occurred during each program phase and milestone decision.

1. Concept Definition

The Patriot Project officially began in August 1965 with the Secretary of Defense's authorization of Concept Definition. This authorization marked the creation of the Patriot Project Office at Redstone Arsenal in Huntsville, Alabama.[9] The long-range plan for Patriot, formerly called the SAM-D (Surface-to-air-missile-Development), was to replace both Hawk (Homing-all-the Way-Killer) and Nike Hercules air defense weapons.[10] In August 1966, the Raytheon Company won a five month, $2.5 million contract to define the concept of the system.

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[8]"Acquisition Strategy for Patriot Program", Patriot Project Office, September 1993, pp. 8-9.

[9]Adapted from a case study entitled, "Defender (Patriot) Project History", September 1993, p. 1.

[10]Ward, Bob, "Army Surface to Air Missile (SAM) Awaits Okay; Use by Navy Also Eyed", Huntsville Times, Oct 8, 1965, p. 1.

2. Advanced Development

The completion of Concept Definition and the beginning of the Advanced Development phase occurred in May 1967. Prior to Advanced Development phase, the Source Selection Evaluation Board and Source Selection Advisory Council conducted an extensive review of four proposals for the advanced development of the SAM-D (Patriot) missile system. These proposals came from four industrial firms: Radio Corporation of America, General Electric Company, Hughes Aircraft Company, and Raytheon. The Commanding General, Army Materiel Command, acting in the capacity of SAM-D Contract Definition Source Selection Authority, decided that firm fixed price contracts for Subphase B of the contract should be awarded to Radio Corporation of America, Raytheon Company, and Hughes Aircraft Company.[11]

The four proposals were evaluated by a Source Selection Evaluation Board from January 3 to March 24, 1967. On May 18, 1967, results of the board were announced; they selected Raytheon's proposal and awarded the company a $2.1 million letter contract. The entire development contract was estimated at $1.1 billion, with over $100 million allocated for the Advanced Development of the system and over $1 billion for follow-on production.[12] Raytheon officials attributed

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[11] Ibid.

[12] "Raytheon Wins $2.1 million Sam-D Contract", Based on information stated in a Raytheon Newsletter, 1967, p. 1.

attributed their success in winning both contracts to an impressive array of company-financed Internal Development Programs, such as the Ferrite Array Demonstration (FAD), work on microelectronic circuits, advances in digital computers, new guidance techniques, and advanced concepts in command and control and logistics. The contractor proved its ability to integrate these technologies in November 1969 with the first launch of the Advanced Development missile.

3. Engineering Development

February 1972 marked the completion of Advanced Development. Upon completion of this phase, the Defense Systems Acquisition Review Council (predecessor of the Defense Acquisition Board) conducted a readiness review of the Patriot system. The following month, the Patriot Project Office received approval from the Deputy Secretary of Defense to enter the Engineering Development phase of the project. During Engineering Development, Raytheon was subsequently awarded a Cost Plus Incentive Fee, Award Fee contract, with incremental funding through calendar year 1977[13].

In February 1974, the Patriot Office was directed by the Secretary of Defense to halt the project for 24 months to demonstrate the Track-Via-Missile (TVM) guidance concept.

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[13] "Defender (Patriot) Project History", Patriot Project Office, September 1993, p. 1.

This "Proof of Concept" requirement resulted in a restructuring of the Patriot project by a letter contract modification on February 11, 1974. On June 6, 1974, a DSARC/DAB reviewed the Army's proposal, which redirected the Patriot Project. The recommendations of the DSARC/DAB were published by memorandum on June 27, 1974, with the following concurrent efforts approved by the Deputy Secretary of Defense:

- Track-via-missile (TVM) Proof-of-Principle (POP) firing program.
- A minimum development effort to permit continuation of Patriot II (an austere version of Patriot) into full-scale development after successful completion of POP.
- A cost reduction effort; and
- A complementary effort to examine backup guidance options.[14]

After several successful guidance flight tests and an electronic counter-measures (ECM) flight test in December 1976, the program received approval in January 1976 to resume Full Scale Engineering Development. Raytheon was awarded a 49-month, $425 million contract for completion of Patriot system development on August 4, 1976. The contract stated that Patriot would "design, build, and test four sets of tactical Patriot equipment for the Army".[15] The contract

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[14] Ibid.

[15] "Patriot Rolls On", Air Defense Bulletin, November 1977, p. 1.

included Producibility Engineering and Planning (PEP) efforts, which were initiated in October 1977[16].

On November 26, 1977, a decision was rendered by the DSARC to accelerate the scheduled initial deployment of the Patriot system by two years. Though the baseline for engineering development remained unchanged, the decision resulted in the elimination of the low-rate initial production phase and the DSARC IIIA. Developmental testing/operational testing III was also eliminated and replaced by a Production Confirmatory Test and a Follow-on Evaluation on the initial production equipment.[17]

Air Defense Artillery Bulletin reported that the first Patriot flight tests were conducted in 1978, the first on June 22, and the second on August 31. The first test was declared a "no test," because the missile self-destructed before target intercept. The second missile launch was successful and performed exactly as programmed; the missile then self-destructed 10 seconds before intercept.[18] By October 1978, a total of 33 Patriot missiles were flight tested. The results of these tests were: 27 successes, two partial successes, one unsuccessful test, and three "no tests."[19]

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[16]Ibid., p. 2.

[17]Ibid.

[18]Sheppard, LTC John, "Patriot Update", Air Defense Artillery Bulletin, October 1978, p. 2.

[19]Ibid.

The first missile-to-missile flight test occurred at White Sands Missile Range in 1979. In this test, a Patriot missile destroyed a Nike Hercules missile on a flight profile similar to an anti-ballistic missile at high altitude.

Developmental Testing and Operational Testing II (DT/OT II) officially commenced on 19 November 1979. DT/OT was delayed for several months due to problems with system hardware and software. OT-type mini-war tests were conducted but a full test of Patriot's ability to operate as a system could not be evaluated. Shortfalls were identified in reliability, maintainability, target identification, and electronic counter-counter measures (ECCM) performance.[20] These DT-type search and track tests, which began in April 1980, demonstrated shortcomings regarding readiness for deployment. When testing resumed, the usual DT/OT sequence was reversed and the tests were partially melded. After several interruptions, the test concluded on March 28, 1980.

4. Limited Production

Six months after completion of DT/OT II, the system entered limited production.[21] On September 1980, the ASARC/DSARC approved Milestone III, and the project proceeded

[20] "Defender (Patriot) Project History", Patriot Project Office, September 1993, p. 2.

[21] Document generated by the Patriot Project Office, Huntsville, Al, titled "Patriot Executive Summary", December 1991, p. 2.

to Phase III, Production and Deployment. The approval to enter this phase was initially for limited production only, with a future decision to enter full scale production contingent on the results of initial production tests that were planned for the 1982-1983 timeframe. The Council also directed the Patriot Office to carry out its growth program and prescribed a series of four test units to display system performance, reliability, and maintainability before authorizing a full production decision.

In 1981, the Patriot Preplanned Product Improvement (P3I) Program was initiated. This program was in keeping with Secretary of Defense Frank Carlucci's Initiative #2 - Preplanned Product Improvement (P3I), which directed an evolutionary approach to minimize technological risk, consciously insert advanced technologies, and incorporate planned upgrades.

In early 1981, the Patriot office developed a concept known as the Patriot Maintenance Enhancement Program. With the exception in the area of maintainability, test results demonstrated that the corrective measures had been effective in the elimination of previously identified shortcomings. In November 1981, a Maintenance Improvement Program (MIP) was established to address the maintainability shortfall, with particular emphasis on improving the reliability of Patriot's fault localization capability.

5. Full Production

Full Production (Milestone III) approval was granted in April 1982. Raytheon was subsequently awarded a cost plus-incentive fee (CPIF) contract worth $110,307,690. This CPIF contract allowed the contractor to continue its basic engineering development and P3I efforts.[22] From April to June 1982, the project office conducted a Development Confirmation Test Series. These tests were part of a program mandated by the Secretary of Defense to display capabilities not thoroughly shown in earlier development and operational tests. The system received a successful rating of 82 percent, with 52 successes out of 63 scorable flights.[23] Upon test completion, the first production set was delivered in June 1982.

The Patriot system's Initial Operational Capability (IOC) for CONUS (Continental United States) occurred on June 1983. The unit that achieved this IOC was 1st Battalion, 43d Air Defense Artillery, at Fort Bliss, Texas.

Follow-on Evaluation (FOE) testing was conducted by the Operational Test and Evaluation Command (OPTEC) from May through July 1983. This $25 million evaluation consisted of two tests: FOE I, which examined the soldiers' ability to man

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[22] "Historical Report", Patriot Project Office, October 1, 1987 to September 30, 1988, p. 3.

[23] "Patriot Confirmation Testing Completed", Air Defense Magazine, April-June 1982, p. 46.

the system; and, FOE II, which was a four-phase comprehensive test of the system itself.[24] Phase I was an evaluation of the Patriot missile's effectiveness in an electronic counter measure (ECM) environment. Phase II, known as the Search/Track Phase, was scheduled for June 1983, with Phase III, the Maneuver Phase, scheduled during the first two weeks of the following month. The fourth phase, Live Fire, was scheduled for July 16 to August 22, 1983.

The tests, however, were terminated on July 28 due to problems with system reliability and maintainability, primarily caused by radar down time. As a result, the Under Secretary of Defense, James Ambrose, directed that the European deployment of Patriot be delayed until the "...system's reliability matured to an acceptable level."[25] The commandant of the United States Army Air Defense School, Fort Bliss, Texas, addressed the problem in the June/July 1983 issue of Air Defense Magazine:

> ...the equipment didn't work as advertised. System experts forecast that shortcomings could be corrected in five weeks. Army leadership and ADA community were not satisfied that the shortcomings could be corrected, so the Patriot program was taken off of the IOC concept and placed on a milestone schedule.[26]

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[24] Strawther, Craig, "Patriot Testing, Training Continues", Air Defense Artillery Bulletin, July 1983, p. 3.

[25] Infante, Major General (Ret) Donald R., "The Testing", Air Defense Artillery, p. 28.

[26] Maloney, Major General (Ret) James P., "Intercept Point", Air Defense Artillery, Winter 1985, p. 2.

As a result, the system could not meet its initial operating date of April 1984 and was returned to the contractor for repairs. The main objective was to ensure that all problems were corrected prior to fielding, precluding the release of any substandard Patriot systems.

The new schedule was broken down into three milestones. Milestone I involved training and preparation, and certification of personnel and equipment to begin 16 weeks of collective training. Another condition for Milestone I centered on the supportability of the equipment through the collective training period and the 14-week FOE III evaluation. Upon certification by the United States Army Air Defense School (USAADS), Milestone II consisted of the successful completion of collective training. The third milestone was the successful completion of an FOE II-type evaluation.

The system was returned to the contractor and a second FOE was scheduled to begin in February 1984.[27] In June 1984, the contractor completed required equipment upgrades and reliability verification testing. Upon completion of the testing, the Patriot Project Manager briefed the Under Secretary of the Army and the Vice Chief of Staff of the Army on the readiness of the system. A memorandum from the Under Secretary of the Army to the Program Executive Officer

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[27] "Fielding of Patriot Delayed", Air Defense Artillery, Fall 1983, p. 46.

followed, directed him to "conduct a demonstration of the Advanced Tactical Patriot and prepare for a decision Milestone upon completion of the Demonstration for entry into Follow On Evaulation III.[28]

The system was certified ready in July 1984 and testing was initiated. While officials signed this agreement, U.S. troops were completing their collective training in preparation for the Follow-On Evaluation (FOE) III on July 16, 1984. Originally scheduled to begin in February 1984, this ambitious 10-week, live-fire operational test was conducted at White Sands Missile Range, New Mexico, by the Operational Test and Evaluation Command (OPTEC) and involved over 2,000 people.[29] A maneuver phase was conducted at the North MacGregor maneuver area at Fort Bliss, Texas. The evaluation's purpose was to show the improvements in system reliability gained during the year after conclusion of FOE II. The focus of the examination included the areas of mission performance, reliability, availability, maintainability, and survivability.[30]

The success of FOE III proved to be a "shot in the arm" for the Patriot project. Final test results demonstrated:

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[28]"Defender (Patriot) History", Patriot Project Office, September 1993, p. 3.

[29]Ibid.

[30]Infante, Major General (Ret) Donald R., "The Testing", Air Defense Artillery, Winter 1985, p. 28.

- Fire control section major end items remained operational for over one thousand hours to eliminate "infant mortality" problems.

- Maneuverability of the system, which included an extensive field problem conducted tactically under various weather and nuclear, chemical, and biological protective postures.

- Search and tracking capability during 16-large scale search and track trials, with instrumentation recording all of the tactical decisions by man or machine in the conduct of the air battle against 600 sorties.

- The operational effects of human fatigue after 60 days of intensive operations. This period included four sucessful live-fire engagements against full-scale fighter aircraft emitting electronic countermeasures.

- A one hundred percent increase in fire unit availability over FOE II.

- A mean time between failures for the entire system that was 117 percent of the requirement stated in specifications.

- A 90 percent launcher operational availability.

- A 92 percent successful engagement rating against 262 hostile target presentations.[31]

The FOE III test concluded in September 1984, and one month later, the Secretary of the Army authorized the conditional release of equipment for European deployment. 4th Battalion, 3rd Air Defense Artillery (currently 4th Battalion 43d Air Defense Artillery) was the first Patriot battalion deployed to the Federal Republic of Germany (FRG). The battalion shipped equipment and an advanced element to Giessen, FRG, on December 5, 1984. The remainder of the

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[31] Ibid., p. 29.

battalion deployed in January 1985. Two months later, the battalion achieved Patriot's first initial overseas operation capability within United States Army Europe (USAREUR). On April 12, 1985, Patriot officially joined the North Atlantic Treaty Organization (NATO).

During the same year, the Patriot Project Office drafted a Requirements Operation Capability (ROC) document for the Preplanned Production Improvement (P3I) Program and initiated the Reliability and Maintainability programs. The intent of this P3I program was to develop the capability to counter future electronic counter measure threats.

An Anti-tactical Missile PAC-2 Development Contract worth $51,816,354 was awarded to Raytheon in August 1986. August also signified the first deployment of PDB-1 software outside the Continental United States (OCONUS) in August, with Continental United States (CONUS) occurring the following month.

On September 11, 1986, a Patriot missile intercepted a lance missile during a flight test at White Sands Missile Range, New Mexico. The intercept occurred at an altitude of 26,000 feet and eight miles downrange from the Patriot launcher.[32]

On March 31, 1987, Patriot completed negotiations with Raytheon for a firm, fixed-price, multi-year production

[32]Tice, Jim, "Patriot Air Defense Missile Test Successful", Huntsville Times, October 6, 1986, p. 1.

contract. The basis for this multi-year contract was the Multiyear Procurement Strategy, which was approved by the Under Secretary of Defense for Acquisition on October 19, 1985, and Office of the Secretary of Defense during December 1985. The $3.55 billion contract, awarded in March 1986, represented the production of the system from fiscal year 1981 through 1987. The contract called for the production of 45 fire units and 4,491 missiles, in addition to the 77 fire units and 2,572 missiles procured from Raytheon in previous buys.[33]

With production stable, subsequent efforts focused on support of the system. Facilities for re-certifying and refurbishing missiles became operational in August and December 1987.[34]

On March 17, 1988, the original Anti-tactical Missile Contract was modified to include a letter contract for Multi-mode seeker guidance technology. The letter contract totaled a not-to-exceed ceiling amount of $5,800,000, making the total contract worth $57,616,354.[35]

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[33] "Despite Some Glitches, the System is Performing Well in the Field", Military Logistics Forum, November-December 1987, p. 46.

[34] "Defender (Patriot) Project History", Patriot Project Office Document, September 1993, p. 3.

[35] "Historical Report", Patriot Project Office, October 1, 1987 to September 30, 1988, p.3.

firing units through the AN/TSQ-73 Missile Minder Command and Control System. This software upgrade provided new features and capabilities in countermeasures, communications, computer processing, maintenance, and missile performance, which included the initial anti-tactical missile engagement capability. An article in Research, Development, and Acquisition (RD&A) Bulletin, titled "Life Cycle Software Engineering Centers", cited the success of this software enhancement:

> The original Patriot system was designed to engage high performance aircraft. The capability of the system was subsequently expanded to include tactical ballistic missiles. The enhancements for improving capabilities included software programs at a cost of $32 million. However, the cost of making the same improvements in hardware or procuring a new missile system was estimated to far exceed $32 million.[36]

The effectiveness of this integration was tested during Return of Forces to Germany (REFORGER) in 1988.

After the successful completion of a series of confirmatory tests, a new version of the Patriot missile with improved anti-tactical missile capability was cut into production in December 1988. This program, known as the Patriot Advanced Capability-1 (PAC-1) Missile Program, was a software-only modification that provided Patriot with a

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[36] "Life Cycle Software Engineering Centers", Army R,D, and A Bulletin, November-December 1990, p. 28.

limited self-defense against one class of TBMs[37]. On December 1, 1988, the PAC-1 program was completed.

The Patriot Advanced Capability-2 (PAC-2) Missile Program followed, with the first missile deployment occurring in September 1990, five months ahead of schedule. The accelerated deployment was the result of an extensive effort by the project manager. This key decision to accelerate the deployment resulted in the fielding of the first PAC-2 missiles to Desert Shield and provided Patriot units in Saudi Arabia the capability to counter Scud missile attacks in January 1991. Additional decisions to accelerate the PAC-2 missile production occurred as the events of Desert Shield and Desert Storm unfolded.[38] In September 1990, the President directed Foreign Military Sales (FMS) of Patriot systems to Israel; another FMS agreement with Saudi Arabia was reached two months later.

July 1992 marked many significant events in the Patriot project. These events included a Patriot Advanced Capability (PAC III) Operation Requirements Document, the PDB-3 Quick Response Program software release, a Radar Enhancement Phase II production decision (MS III) approval, and a Quick Response Program (QRP) production decision (MS III) approval.

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[37]Weeks, Paul, "The Story of Patriot", Air Defense Artillery Yearbook, Jan 1993, p. 40.

[38]"Defender (Patriot) Project History", Patriot Project Office, September 1993, p. 4.

D. HOW THIS STRATEGY IS CURRENTLY EMPLOYED IN THE PATRIOT PROGRAM

Today's acquisition strategy for Patriot is to continue to provide a baseline system capable of countering the evolving threat, while minimizing technological risks and enhancing system capability through planned upgrades of deployed systems.[39]

To achieve these goals, the Patriot program has incorporated two interrelated programs, the Patriot Growth Program and the Patriot Advanced Capability-3 (PAC-3) Program.

The Patriot Growth Program is based on an evolutionary strategy that consists of a series of preplanned product improvements (P3I) and enhancements derived from the Reliability, Availability, and Maintainability (RAM) Growth Program. This acquisition strategy includes an intent to "...minimize the time and cost of satisfying an identified, validated need consistent with common sense, sound business practices and the basic policies established by DoD Directive 5000.1, Defense Acquisition."[40] The Patriot Growth Program's primary goal is to recover lost battle space. The Growth Program will enable the Patriot system to counter stealth aircraft, low-altitude cruise missiles, high velocity

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[39], "Acquisition Strategy for Patriot Program", Patriot Project Office Document, September 1993, p. 2.

[40]<u>Ibid</u>., p. 8.

tactical ballistic missile (TBMs), and defeat enemy High Value Airborne Assets (HVAA), such as Airborne Warning and Control System (AWACS), Reconnaissance, Surveillance and Target Acquisition Aircraft (RSTA), Stand Off Jammers (SOJ), and Tankers (See Figure 2-1).

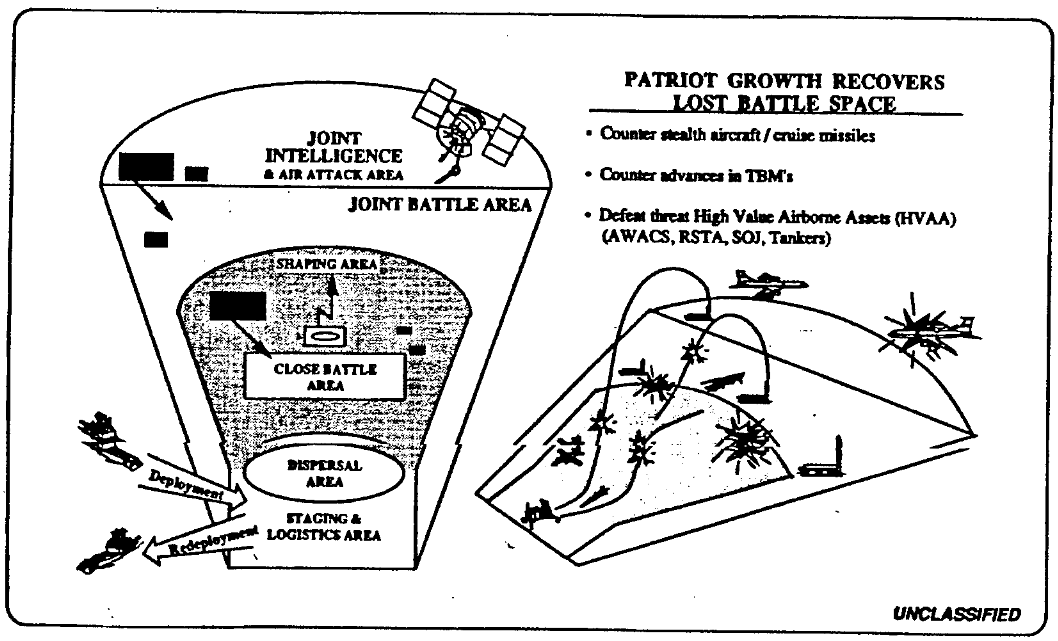

Figure 2-1 Patriot Growth
Source: Patriot Project Office, September 1993

Patriot Advanced Capability Program-3 (PAC-3), a subcomponent of the Patriot Growth Program, is a newly developed program designed to reduce the technological advancement offered by these systems. PAC-3 is divided into four configurations that are managed as ACAT III programs at the program executive officer level.

To meet requirements defined in the Operational Requirements Document for the Patriot Advanced Capability (PAC-3) program, the Patriot Project Office proposed six, interrelated areas for improvement:

- Detection and engagement of lower observable targets. The threat includes lower observable TBMs and aircraft flying in clutter and/or intense electronic countermeasures (ECG) environments.

- Positive identification/classification of air breathing threats (ABTs) and TBMs. PAC-3 must be able to positively identify and/or classify/categorize ABTs and TBMs. Additionally, PAC-3 must discriminate between valid targets and penetration aids or debris.

- Increased firepower and lethality. PAC-3 must increase multiple simultaneous engagement and track handling, improve lethality against a more stressing target and decrease missile reload times.

- Survivability. Patriot upgrades must counter the growing lethality of the modern battlefield and advances in enemy recognizance, surveillance and target acquisition (RSTA).

- Force synchronization integration. Patriot must operate with other battlefield operating systems (BOS) and have compatibility with future Army, Joint and Combined Services command, control, communications, and intelligence (C3I) architectures.

- Extended Range. Patriot must operate at extended rages to disrupt enemy use of airspace.[41]

The Growth Program groups the system modifications into configurations that are scheduled for fielding in the same time-frame (See Table 2-1). These configuration groupings include block changes to the hardware and software. Incremental increases in performance will be determined for each configuration, which will serve as benchmarks for configuration testing and user doctrine and tactics development.[42] According to the Deputy Project Manager, approximately 20 significant modifications will be developed and applied to the system over the next five to six years, totaling more than $2 billion in Research, Development, Test and Evaluation, (RDT&E) and production.[43] The modifications to the system are discussed at length in Chapter III of this thesis.

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[41]Ibid., p. 2.

[42]Ibid.

[43]Oldacre, A.Q., "Implementation of Integrated Product Teams in the Patriot Project Office, Patriot Project Office Document, September 1993, p. 1.

TABLE 2-1 CONFIGURATION GROUPINGS FOR PATRIOT MODIFICATIONS

	GROWTH PROGRAM ELEMENT	CAPABILITIES ADDED							
		DEPLOYMENT FUE	ADV. THREAT TBM, CM STEALTH	MULTIFUNCTION	IMPROVED TAC OPS	EXTENDED RANGE	RAM	DEPLOY-ABILITY	INTER-OPERABILITY
QRP CONFIG	RADAR ENHANCEMENTS (QRP) REMOTE LAUNCH PHASE I EMPLACEMENT ENHANCEMENT RADAR SHROUD (NOT A QRP TASK) BTOC/ICC INTEGRATION (NOT A QRP TASK)	1993	● ● ○ ● ○	● ○	● ●	○ ○ ○		○ ●	●
CONFIG 1	EWCC OPTICAL DISK (EMBEDDED DATA RECORDER) GUIDANCE ENHANCEMENT MISSILE (GEM - NOT A CONFIGURATION 1 TASK)	1995	○ ●	●	●	○	○ ●	○	○
CONFIG 2	RADAR ENHANCEMENT PHASE 2 PAC-3 MISSILE CLASSIFICATION, DISCRIMINATION, IDENTIFICATION (CDI) PHASE 1 COUNTER-ARM COMMUNICATIONS ENHANCEMENT - RLRIU UPGRADE	1996	● ● ● ●	● ● ●	● ● ○	○ ○ ○	●	○ ●	○ ●
CONFIG 3	RADAR ENHANCEMENT PHASE 3 CDI PHASES 2 AND 3 REMOTE LAUNCH PHASE 3 LAUNCH POINT DETERMINATION COMMUNICATION ENHANCEMENT	1998	● ●	● ●	● ○	● ○	○	○	

● - PRIMARY ○ - SECONDARY

UNCLASSIFIED

Source: Patriot Project Office Briefing, September 1993

Pending a favorable Milestone Review in February 1994, the Patriot project will enter an Engineering and Development Phase during the second quarter of fiscal year 1994. The remainder of the year will integrate system performance demonstrations, which will occur after hardware and software testing, and will culminate in EMD flight tests against electronic counter measure emitting threat targets.[44] EMD will include an in-process review for entry into limited rate initial production (LRIP). EMD will be followed by a Milestone III decision, which will allow the project to proceed into the production and deployment of the PAC-3 missile.

E. ANALYSIS OF THE EVOLUTIONARY ACQUISITION/PREPLANNED PRODUCT IMPROVEMENT STRATEGY USED IN THE PATRIOT WEAPON SYSTEM IN TERMS OF COST, PERFORMANCE, AND SCHEDULE

The evolutionary acquisition strategy and the preplanned product improvement strategy were the approaches employed to ensure the success of this project. When the concept for Patriot was first defined in the 1960's, the system was specifically designed to destroy high performance, air-breathing targets. This strategy allowed the air defense community to field the core capability of the system, while allowing the capability for future system upgrades. As the

[44] "Acquisition Strategy for Patriot Program", Patriot Project Office, September 1993, p. 14.

technology, in terms of hardware and software, became available, the product manager subsequently re-examined the operational capabilities of the system to determine how the Patriot missile could be designed to counter the growing tactical ballistic missile threat.

In terms of cost, schedule, and performance, there is no denying the fact that the project suffered "growing pains" while establishing its learning curve. Many Government officials were quick to point out that initial cost estimates, especially those determined during the limited production phase of the project, nearly doubled the estimates established at the inception of the project. Early problem areas also included several scheduling gaps due to production. Another factor contributing to schedule and performance problems in system reliability was deficiencies in the maintenance software used for diagnosing failures within the system. These problems, however, were corrected through the dedicated efforts of the project manager and the contractor.

An acquisition assessment of the Patriot Project was summed up best in a letter written by Colonel Bruce M. Garnett, in response to an article published in a July 1989 edition of Military Forum magazine.[45] Colonel Garnett, the Patriot Project Manager from 1987 to 1991, made the following

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[45]Garnett, Colonel Bruce M., Response to Peter Grier's article, "Which Service Buys Best?", Military Forum, July 1989, pp. 6-7.

key points concerning cost, schedule, and performance of the system:

- Patriot ground equipment showed reliability levels that were more than twice the specified requirements for both production and operational field test (see Table 2-1).

- The multiyear contract for Patriot represented a major milestone for Army Acquisition and perhaps a model for all services. The multiyear contract resulted in a savings of over $445 million, while providing a complete level of program stability.

- Production aggressive preplanned product improvements (P3I) and reliability, availability and maintainability growth programs were on time and under cost.

- After receiving a directive to develop, test, and demonstrate an effective command post, this task was accomplished within twelve months.

- The PAC missile program was put into production and fielded at fifty percent of the originally projected cost, on schedule and exceeding all initial technical capability projections.[46]

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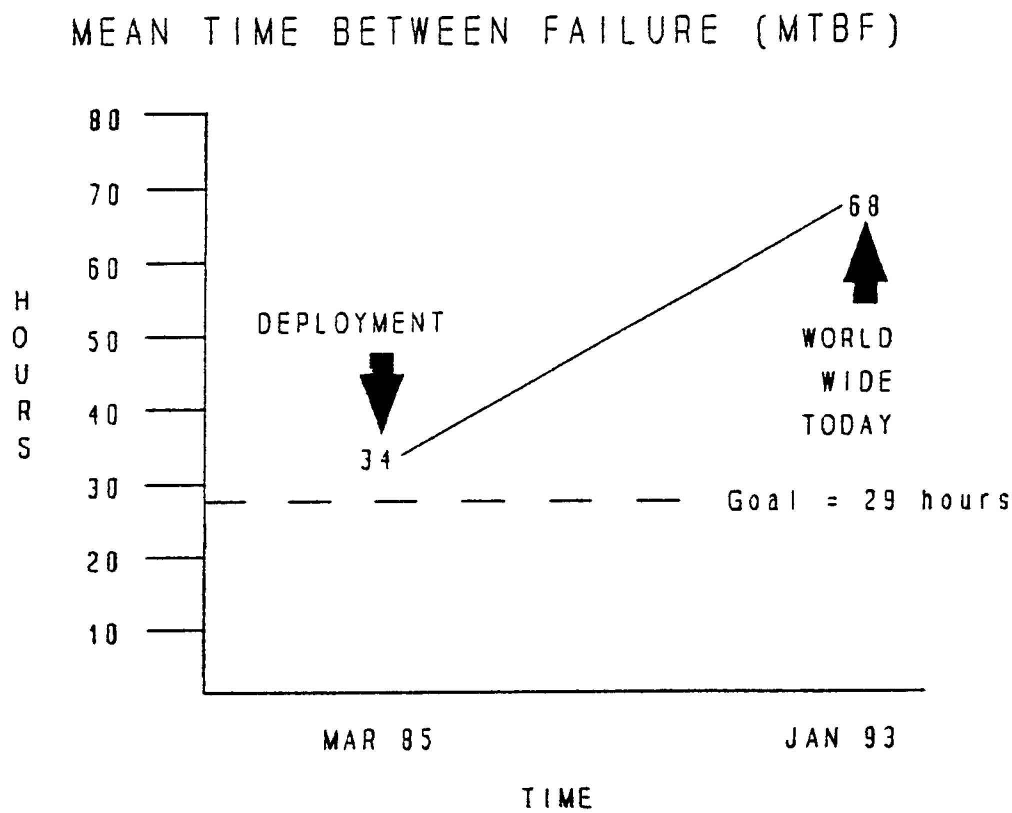
[46] <u>Ibid</u>.

TABLE 2-1 PATRIOT RELIABILITY



Source: Patriot Project Office Briefing, September 1993

III. PATRIOT SYSTEM OVERVIEW

A. PURPOSE OF CHAPTER

This chapter will examine the mission of the Patriot air defense system. It will include a decription of the components of the system, a discussion of the major contractors and subcontractors for the system, and the strategy used by the Patriot Project Manager to handle the evolving threat.

B. MISSION OF PATRIOT

In April 1984, Field Manual 44-15, titled Patriot Battalion Operations, defined the mission of Patriot as providing "very low to very high-altitude air defense of high value assets and ground combat forces."[46] The Air Defense community has redefined Patriot as:

> ...a high-to-medium altitude, long-range air defense missile system which provides air defense of ground combat forces and high-value assets against the air threat of the 1980s and 1990s.[47]

Patriot is designed to cope with enemy defense suppression tactics which may include saturation, manuever, and electronic

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[46]FM 44-15, Patriot Battalion Operations, 1984, p. 1-4.

[47]Document generated by the Patriot Project Office, Huntsville, AL, titled "Patriot", Dec 1991., p. 2.

countermeasures (ECM). Its phased array radar allows the system to simultaneously engage and destroy multiple targets at varying ranges. In coordination with short range, low altitude forward area defense weapons and other ground and air assets, Patriot will provide the necessary air defense for the theater of operations.[48]

C. SYSTEM COMPONENTS AND CONFIGURATION

Patriot, a $13 billion plus program, is credited as having the largest fielding in the history of the U.S. Army Materiel Command (AMC). The system includes 6572 missiles, over 80,000 major end items, 250,000+ spares, tools, and test, measurement and diagnostic equipment (TMDE), 60,000+ publications, and is supported by over 7,500 soldiers.[49]

A Patriot battalion consists of a headquarters and headquarters battery and six firing batteries. The firing batteries or firing units can be controlled by the battalion or fight in an autonomous mode. The major end items of the firing unit are the radar set, the engagement control station (ECS), eight launching station (LS) missiles, the electric power plant (EPP), antenna mast group (AMG), and the Information Control Center (ICC) (See Figure 3-1).

[48] Ibid.

[49] Information is contained in the Patriot Project Office briefing, "State of Patriot", on April 20, 1993.

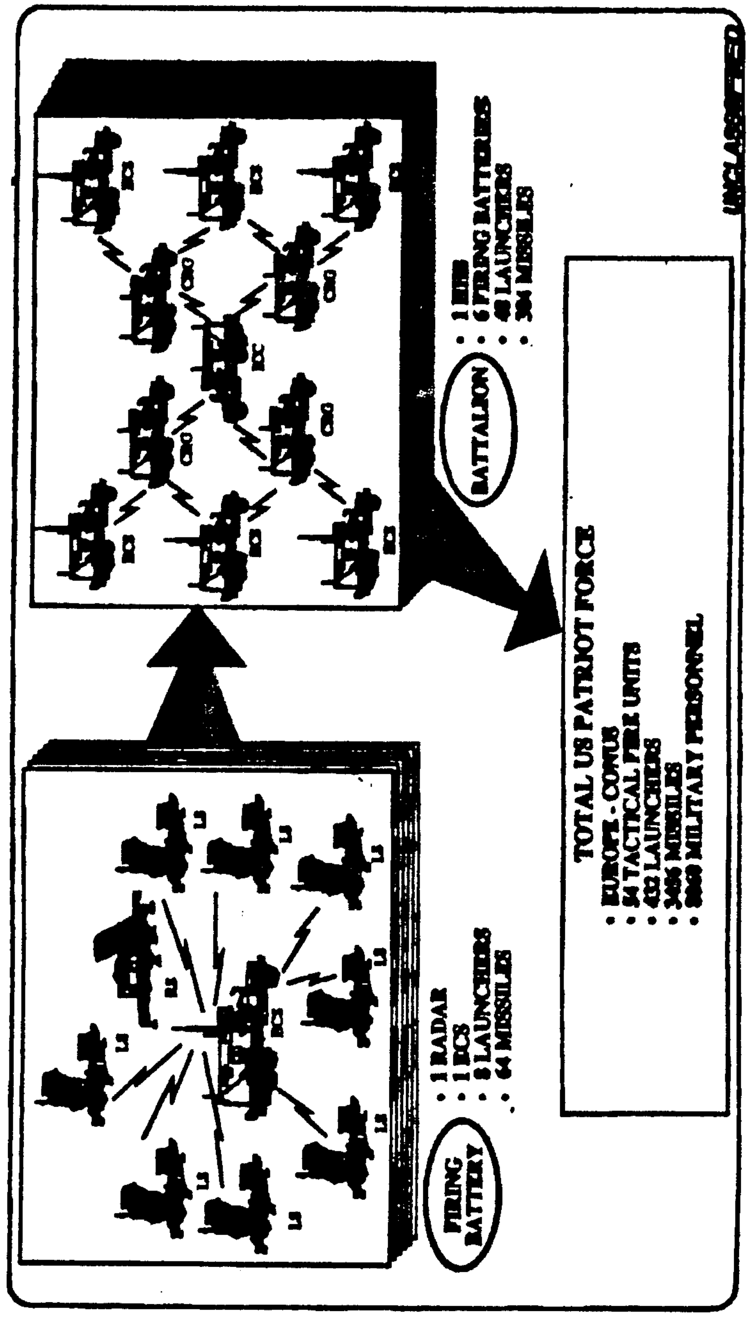

Figure 3-1 Patriot System Configuration
Source: Patriot Project Office, September 1993

1. Radar Set

The radar set consists of a single, multifunction, phased-array antenna with electronic beam steering, which performs the functions of search, detection, identification, tracking, and target illumination, and is also responsible for the issuance of guidance commands to the missile. The radar can simultaneously track up to 50 targets and handle up to five simultaneous engagements at a range of 37 nautical miles.[50] Other features include adaptive ECCM capabality and an advanced signal processor.

2. Engagement Control Station

The Engagement Control Station (ECS) provides the fire direction control at the battery level. It consists of the weapons control computer (WCC), display and control group, three UHF radio terminals, a VHF data link terminal (DLT), and two VHF voice radios.[51] The WCC provides the information necessary for command and control, target identification, tracking and intercept, and battle management.

3. Launching Station

The launching station is responsible for the transport, aim, and launch of four fully self-contained missiles. It also receives, decodes, and executes commands

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[50]Patriot Project Office Document, "Memories", July 1990, p. 7.

[51]FM 44-15, "Patriot Battalion Operations", April 1984, p. 3-6.

from the ECS and communicates status reports to the ECS.[52] The Patriot Quick Response Program (QRP) will enable the launching station to be remotely emplaced up to 10 kilometers from the ECS. This will be accomplished primarily thorough software modifications, resulting in an increased tactical ballistic missile defense and a reduction in visual signature upon missile firings.[53]

A schematic representation of the interactions of the launching station, Engagement Control Station, and radar set is provided in Figure 3-2.

4. PAC-3 Missile

The Patriot project manager considered three approaches for the PAC-3 missile program. One consideration for the program was the multimode missile, which serves a two-fold purpose: first, the multimode missile is designed to buy back battespace against reduced cross section, air breathing threats; and second, this missile effectively increases the tactical ballistic missile footprint to protect assets within a larger area.

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[52] FM 44-15, "Patriot Battalion Operations" April 1984, pp. 3-7.

[53] Patriot Project Office Briefing, "The Patriot Growth Program and the PAC-3 Missile Decision (U)", July 19, 1993, p. 7.

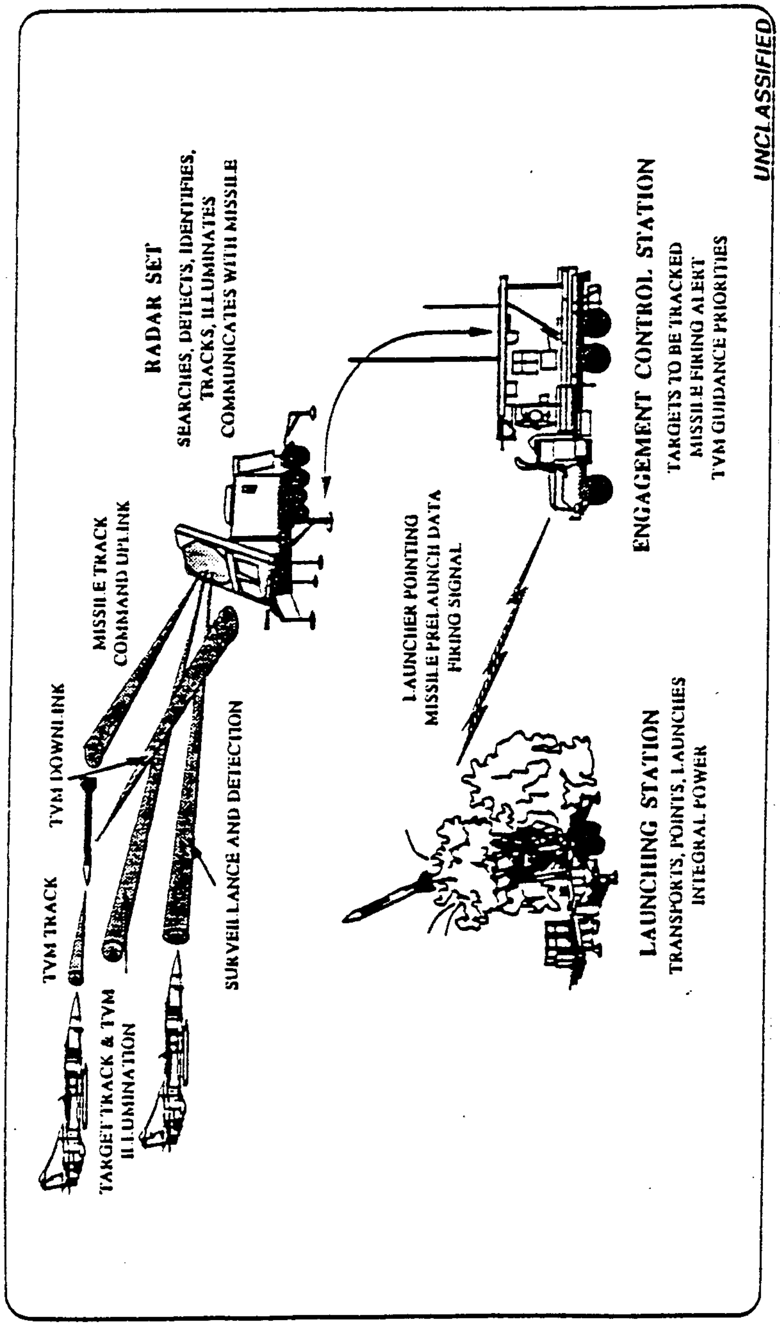

Figure 3-2 Patriot Fire Unit Operations
Source: Patriot Project Office, September 1993

Besides the longer range capability, other characteristics of this missile include an extended warhead proximity kill zone, and an active seeker, which does not require the radar's illumination waveform.[54]

A second consideration for the PAC-3 missile program was Loral Vought's Extended Range Interceptor (ERINT) missile. The ERINT missile is known as a hit-to-kill missile. It is considerably smaller than the Multimode missile. In fact, its size will permit a total of sixteen missiles per launcher vice four for the Multimode.

The third consideration included one of the following three options: a mix of ERINT and existing Patriot missiles; a mix of Multimode and existing Patriot missiles, and a mix of ERINT, Multimode, and existing missiles. According to the the Patriot Project Office, the third alternative will be considered "...only if neither the Multimode nor ERINT can singularly satisfy the ORD requirement and the Multimode/ERINT combination is determined to be cost effective."[55]

In February 1994, the Army recommended the ERINT missile over the Multimode as its PAC-3 missile. This decision was protested by Representative Peter Torkildsen (R-Mass.), who charged the Army with "not abiding by its requirements

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[54]Weeks, Paul, "The Story of Patriot," 1993 ADA Yearbook, p. 42.

[55]Ibid., p. 14.

criteria during the selection of the ERINT missile." [56] The Defense Acquisition Board will consider both systems on April 21, 1994.[57]

D. CONTRACTOR/MAJOR SUBCONTRACTORS FOR PATRIOT

The prime contractor for the Patriot system is the Raytheon Company, Bedford, Massachusetts. The Patriot Project Office refers to Raytheon as "the only contractor possessing the required Patriot experience, expertise, and knowledge necesssary to integrate system improvements into the Patriot system".[58] This relationship dates back to 1967, when the development contract was competitively awarded to Raytheon, who subsequently produced the missile and serves as the integrating contractor.[59] The major subcontractors for the system include the Martin Marietta Corporation, Orlando, Florida, and Thiokol Chemical Corporation, Huntsville, Alabama. Martin Marietta is responsible for the missile and launcher assembly, with the solid rocket motor produced by Thiokol. Other subcontractors include Chamberlain (warhead), Lucas (launchers components), Valley (DLTM cabinet), Brunswick

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[56] "Army Ignored ORD in PAC-3 Decision, Torkildsen Tells Deutch", Aerospace Daily, March 9, 1994, p. 365.

[57] "BMDO Modifying PAC-3 Schedule, DAB Set for April 21", Aerospace Daily, p. 360.

[58] "Acquisition Strategy for Patriot Program," Patriot Project Office Document, September 1993, p. 23.

[59] Ibid.

(radome billet), and Emerson Electronics (power supplies). A total of eleven other subcontractors contribute to the production of the Patriot weapon system.

E. PATRIOT ADVANCED CAPABILITY (PAC) PROGRAMS

A major strategy within the Patriot Evolutionary Acquisition approach has been the development and execution of the Patriot Anti-Tactical Missile Capability (PAC) Programs. The purpose of the PAC programs was to provide a baseline system capable of being modified to cope with the evolving threat.[60] This issue was first addressed in 1983 during a meeting between the project manager, Brigadier General Max Bunyard, and his replacement, Brigadier General Donald Infante. Their discussion focused on how Patriot could combat the growing threat, and how quickly this threat could be addressed.[61]

This session marked the beginning of the PAC-1 and PAC-2 programs. The initial anti-missile capability was first developed in 1988. The PAC-1 consisted of a software-only modification, which enabled a limited-defense capability against one class of tactical ballistic missiles. PAC-2 was developed in 1990 and offered an improved self-defense

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[60]"Acquisition Strategy for Patriot Program", Patriot Project Office Document, September 1993, p. 2.

[61]Weeks, Paul, "The Story of Patriot", Air Defense Artillery Yearbook, January 1993, p. 40.

capability with the following enhancements: a new missile warhead, an upgraded dual fuze, and appropriate software changes to improve the missile's trajectory during intercept.[62]

The PAC-3 seeks to improve upon the capabilities of the existing system. The Patriot office defines the PAC-3 program as "...a combination of integrated complementary system improvements".[63] The improvements involve a number of upgrades to existing system capabilities which include remote launch, intergration between the battalion tactical operations center and the information control center, radar enhancements, an embedded data recorder in the EWCC, and communication upgrades.

F. ANALYSIS OF THE PAC PROGRAMS

The Patriot Advanced Capability Programs I and II have been very successful. The key to this success is the synchronization of system improvements to both hardware and software. In terms of software, updates are scheduled at regular intervals. These updates, which include software only program improvements and hardware related software changes, are grouped in Post Deployment Builds (PDB) that are released to deployed units biannually.

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[62] Ibid.

[63] "The State of Patriot", Patriot Project Office Briefing, September 1993.

A measure of Patriot's success has been the ability of the Project Office to upgrade the system in order to keep pace with the changing threat. The PAC-3 program will result in a number of improvements to a number of system end-items. Projected improvements include an upgraded computer system within the EWCC van. Radar upgrades will include improvements in target acquisition and tracking, anti-tactical missile engagement capability, increased target identification capability, and ease in emplacing the system. The PAC-3 program will also increase the lethality of the system through upgrades to the multimode or ERINT missile. The bottom line with the PAC-3 program is this: PAC-3 will provide increased performance and capability to counter the technological developments of enemy ballistic and tactical missiles.

IV. PATRIOT'S CONTRIBUTION IN DESERT SHIELD/DESERT STORM

A. PURPOSE OF CHAPTER

This chapter will examine the performance of the Patriot weapon system in the Desert Shield/Desert Storm conflict. It will address issues concerning the effectiveness of the weapons system in acquiring, tracking, and engaging Scud missiles, analysis of its effectiveness against Scud missiles, and how the Patriot Project manager has incorporated the lessons learned from Desert Storm into the program.

B. DEPLOYMENT

The decision to deploy the Patriot system to Southwest Asia was in response to the Iraqi invasion of Kuwait on August 2, 1990. The Patriot battalions deployed were part of the 11th Air Defense Artillery, Brigade, Fort Bliss, Texas. These units, along with Avenger fire units and crews from the 6th ADA Brigade, Fort Bliss, Texas, were airlifted by C-5 Galaxies and C-141 StarLifters[62] (See Table 4-1).

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[62]Case, Blair, "A Line Drawn in the Sand," Air Defense Artillery Magazine, Sep-Oct 1990, p. 23.

TABLE 4-1 *ADA DEPLOYMENT

1st Cavalry Division

4th Battalion, 5th ADA
(Vulcan/Stinger)

2nd Armored Division

2nd Battalion, 5th ADA
(Stinger teams)

3rd ACR

(Avenger platoon)

11th ADA Brigade

2nd Battalion, 1st ADA
(Hawk)

2nd Battalion, 7th ADA
(Patriot)

3rd Battalion, 43th ADA
(Patriot)

5th Battalion, 62nd ADA
(Patriot)

6th ADA Brigade

(Avenger fire units)

24th Inf Div (Mech)

4th Battalion, 5th ADA
(Vulcan/Stinger)

82nd Airborne Division

3rd Battalion, 4th ADA
(Vulcan/Stinger)

101st Airborne Div (AA)

2nd Battalion, 44th ADA
(Vulcan/Stinger)

197th Infantry Brigade

(Stinger platoon)

* ADA units deployed, or in the process of deploying, as of September 15, 1990

Source: Air Defense Artillery Magazine, September - October 1990

The Patriot fire units were initially deployed to protect airfields far south of the Kuwaiti border. About 60 Patriot launchers were positioned in Saudi Arabia, with the primary missions against theater and tactical ballistic missiles (TBMs) and any Iraqi aircraft that might be confirmed by satellite reconnaissance as carrying chemical weapons.[63] Follow-on deployments included the defense of the Isreali cities of Tel Aviv and Haifa. The TBM threat was thought to

[63] "Army's Patriot: High-Tech Superstar of Desert Storm", Army, March 1991, p. 40.

consist of Soviet-built Scud B missiles, which delivers a 2,172-pound warhead, and an enhanced version of this missile, known as the Al Hussein, which is capable of delivering a 3,281-pound warhead.[64] These long-range missiles were capable of hitting targets deep inside Saudi Arabia.[65]

At the time of the deployment, the project manager made a key program decision which ultimately influenced the overall effectiveness of Patriot in the Desert Storm conflict. At the time of the Iraqi invasion, the fielding of the PAC-2 missile was scheduled to occur at least six months after the deployment of its enabling software package known as PDB-3 (Post Deployment Build).[66] The PAC-2 missile is an improved version of PAC-1. Both missiles have warheads that are relatively the same size, but the PAC-2 boasts improvements in the size of the fragment and the velocity and spray pattern needed for a high lethality kill.[67] Based on the capabilities of the PAC-2 missile, the project manager pushed Raytheon to compress the missile production ramp-up schedule, which accelerated the full capability deployment date to

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[64] Ibid., p. 26.

[65] Ibid.

[66] Weeks, Paul, The Story of Patriot, Air Defense Artillery Yearbook, Jan 1993, p. 41.

[67] Ibid.

January 1991. This decision enabled the Patriot system to defeat Iraqi Scuds with the best missile available.[68]

C. PATRIOT ENGAGEMENT AGAINST SCUD MISSILE ATTACKS

The actual speed of the Patriot missile is classified. The March 1991 issue of Army Magazine lists the unofficial speed at which a Patriot missile exits the launcher at Mach 3, accelerating to a speed of Mach 6 at intercept.[69] The incoming speed of an Iraqi-modified Scud missile, in comparison, is approximately Mach 4.75.

The historic first intercept of a Scud missile occurred on January 17, 1991, when A Battery, 2-7 ADA, engaged a target in Dhahran, Saudi Arabia. Most of the intercepts occurred at ranges of 15 miles or less, with the acquisition of the Scud missiles occurring at ranges of 35 to 50 miles.[70] Within days, a total of 33 Scuds were engaged.

D. ANALYSIS OF PATRIOT'S PERFORMANCE IN DESERT SHIELD/DESERT STORM

The performance of Patriot in Desert Shield/Desert Storm was scrutinized intensely in the months following the war. The Army declared the official success rate at more than 80

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[68] Ibid., p. 41.

[69] "Army's Patriot: High-Tech Superstar of Desert Storm," Army, Mar 1991, p. 41.

[70] Ibid.

percent in Saudi Arabia and more than 50 percent in Israel.[71] Theses figures were later revised to 70 percent and 40 percent respectively.

However, a number of reports were published which questioned the effectiveness of the Patriot weapon system. A report published by the General Accounting Office on September 33, 1992, contends that "data does not exist to conclusively say how well Patriot performed."[72] The report was generated by Congressman John Conyers, Jr., Chairman of the Legislation and National Security Subcommittee, Committee on Government Operations, and Congressman Frank Horton, the ranking minority member, and was in response a hearing held before the same subcommittee on April 7, 1992. During this hearing, the Director of Army Issues, General Accounting Office, testified before the subcommittee that the Project Manager's claims of the Patriot's success during Operation Desert Storm were not supported by the data.[73] The report states that "the Army had also recognized the limitations of its assessment, and a few days prior to the Subcommittee's hearings, the Army

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[71]"Patriot: A Reason to be Proud", Air Defense Artillery, Jan-Feb 1993, p. 25. The Army has classified, for national security reasons, the number of kills that Patriot is credited with achieving during Desert Storm. Therefore, the success of the system is provided in percentages, rather than exact numbers.

[72]General Accounting Office, GAO/NSIAD-92-340, "OPERATION DESERT STORM; Data Does Not Exist to Conclusively Say How Well Patriot Performed", U.S. Government Printing Office, September 22, 1992.

[73]Ibid., p. 1.

hearings, the Army revised its assessment."[74] The review of available background information revealed that:

- Although the Patriot was not originally designed to engage an extended range, high-speed ballistic missile, the Army quickly incorporated changes to provide the Patriot with this capability. The Army and the prime contractor, in coordination with the intelligence community, identified, assessed, and incorporated software modifications to provide the Patriot the capability to engage the faster missiles.

- At the time of the Iraqi invasion, only three PAC-2 missiles were in the Army's inventory. By the end of the month, 600 improved Patriot missiles were deployed to Southwest Asia.

- The Patriot missile does not have to hit the enemy warhead in order to destroy it. Each Patriot missile contains a fuze, which senses the presence of a target, and a warhead with (1) metal fragments to destroy or disable the target and (2) an explosive to propel the fragments to the target. When the Patriot missile flies close enough to the target to cause the Patriot's fuze to issue a detonation order, the fragments are propelled at high velocity toward the target. The Patriot fragments that do not cause the target's warhead to explode can damage the warhead to the extent that it will either not explode or will not explode with full force when it hits the ground or will go off course.[75]

The report states that the Army did not collect performance data since Patriot was operating in a warzone and not on a test range. Under test range conditions, the performance of the Patriot system could be recorded with high-speed photographic equipment, portable data recorders, and telemetry equipment. During Desert Storm, with the notable

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[74] Ibid.

[75] Ibid., p. 2.

exception of data recorders that captured a few engagements in Israel, there was not the means to evaluate the exact number of targets that were killed.[76]

The report further contends that Patriot computers processed target information that was sometimes preserved on tape or in hard copy.[77] This information, however, cannot be used to determine whether the warhead of the Scud was destroyed during intercept. The information often included the following:

- When the Patriot system detected a target;
- Whether the target detected by the system met the speed criteria of the modified Scud, 2,000 to 2,200 meters per second;
- Whether the Patriot system, or the system's operator, had determined that the target would impact an asset being protected by the Patriot and launched Patriot missiles toward the target, and
- Whether the Patriot system reported that it had probably killed or failed to engage the target's warhead.[78]

The Patriot Office offers an interesting paradigm they call "The Patriot/Scud Ground Damage Paradox" (See Figure 4-1). This model states that scientifically there was a limited value level of data, from which one could "...assume that either Patriot did its job, or Patriot didn't do its

[76]Ibid., p. 3.

[77]Ibid. p. 5.

[78]Ibid, p. 5.

job".[79] The paradox centers on the fact that there were a number of aerial explosions which occurred as Patriots intercepted Scud missiles, with no reported ground damage during Operation Desert Storm. This implies that warheads must have been destroyed by Patriot missile intercepts, since warheads that are not destroyed in the air would result in significant ground damage.

Dr. Peter Zimmerman, a physicist and expert in imagery analyst at the independent Center for Strategic and International Studies in Washington, D.C., offered this perspective of the "Patriot/Scud Ground Damage Paradox". In his testimony before the House Government Operations Committee, Dr. Zimmerman stated that:

> The only way to know (Patriot's effectiveness) is to look at the ground. Patriot reduced the damage expectancy from one-and-a-half to four in Israel. This is absolutely not the performance of a system that failed. I believe the Patriot system was an astounding success, even if it only cut in half the severe damage that might have been otherwise produced by the Scuds. Patriot was used to defend against a threat well beyond the outer edge of its original design envelope, and it frequently succeeded. For the first time in history ballistic missiles launched in combat were countered by defending interceptors. That's important. We need to push ahead with research and development for advanced tactical ballistic missile defenses.[80]

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[79] "Desert Shield/Desert Storm Observations and Lessons Learned", Patriot Project Office Briefing, March 13, 1991, p. 4.

[80] Stone, Michael P.W., "Closing the Patriot Controversy", Air Defense Artillery, January - February 1993, p. 27.

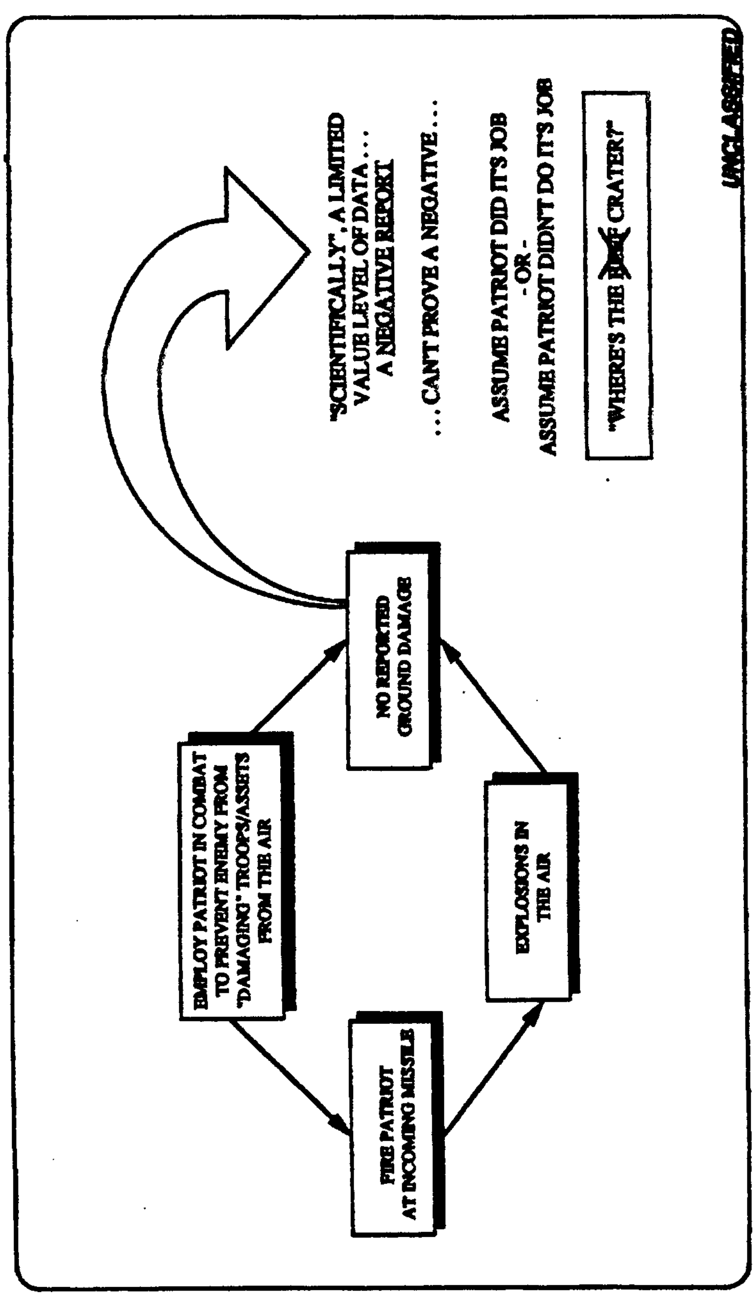

Figure 4-1 The Patriot/Scud Ground Damage Paradox
Source: Patriot Project Office, March 1991

In an analysis of how effectively Patriot performed during the Desert Storm conflict, the former Secretary of the Army, Michael P.W. Stone, offered the following observations:

- On the strategic level, Patriot was an important factor in the Israeli decision to avoid a direct entry into the Gulf War.
- At the tactical level, Patriot accomplished a historic mission: successfully engaging, intercepting and killing incoming ballistic missiles.
- On the psychological level, Patriot provided a great mental lift for the Israelis, Americans and freedom-loving people around the world by demonstrating the effectiveness of the American technology. And most important,
- On the human level, the Patriot saved lives.[81]

Overall, the Patriot system performed well in Desert Storm. Desert Storm was a true operational test of a system that had never fired a missile under actual wartime conditions. When analyzing Patriot's performance, it is important to consider the following issues. First, Patriot was originally designed to defeat high performance aircraft only. The requirement for the system to counter a ballistic missile threat was not seriously addressed until the 1980's. The flexible nature of an evolutionary strategy and the Preplanned Product Improvement approach permitted the Project Manager to upgrade his system as new technologies were

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[81]Ibid., p. 28.

available. The result was a missile system which possessed the capability to defeat ballistic missiles.

Second, the Project Manager was willing to take a calculated risk. He convinced Raytheon to accelerate the production of PAC-2 missiles to ensure missiles were deployed by January 1991. His decision allowed Patriot firing units to engage Scud missiles with the best Patriot missile available.

This decision also symbolizes the importance of a strong Project Manager/Prime Contractor relationship. This Patriot/Raytheon "marriage" has lasted for nearly thirty years and has contributed to the stability of the project.

Desert Storm provided the Project Manager with a number of lessons learned. In the area of acquisition contracting, DoD should publish a new acquisition regulation clause that addresses rapid wartime response. Contracts should include surge options to facilitate increased production during mobilization and contractor support requirements in the warzone.

Problems areas also included maintaining adequate stockage level of spare parts, procedures for returning parts, a requirement for improved test and training equipment, and inadequate power required to sustain continuous operations.

The project office's current strategy focuses on improving the system through the Quick Response Program (QRP). This program allows the Patriot Project Manager to implement hardware and software changes to the system and field these changes in an expedient manner. The specific hardware improvements include: radar and missile enhancements, an upgraded communication system, a remote launch capability, and the addition of an embedded data recorder in the Weapons Control Computer (WCC). Post Deployment Build (PDB) software versions will continue to be fielded every six months. This fielding approach should reduce the additional problems that are often created when hardware and software changes are not properly integrated.

V. CONCLUSIONS AND RECOMMENDATIONS

A. DISCUSSION OF CONCLUSIONS AND RECOMMENDATIONS

The evolutionary acquisition strategy used throughout the lifecycle of the Patriot project was employed successfully. This strategy optimized both the efficiency and effectiveness of this system's acquisition, allowing the project manager to field a core capability of the system while planning for future upgrades. The result of the strategy is a weapon system that has evolved from a platform that was originally designed to defeat high performance, air breathing aircraft to a system which currently is the only fielded system with a capability of engaging tactical ballistic missiles.

The Preplanned Product Improvement (P3I) strategy was instrumental in allowing this system to evolve and counter a dynamic threat environment. The Patriot Weapon System's anti-ballistic missile capability offers a good example of P3I in action.

In terms of the lessons learned from Patriot's involvement in Desert Storm, the major modification to the acquisition strategy of the Patriot project was the development of the Quick Reaction Program. This program allows the Patriot Project Manager to implement hardware and software changes to the system and field these changes in an expedient fashion.

In a sense, it serves to streamline the process by allowing the authorization for these decisions to occur at the Program Executive Officer level.

A number of lessons learned from the Patriot Project that can be applied to future missile systems. These lessons learned are listed below.

Define the requirements first. After the requirements for the system are thoroughly defined, the acquisition strategy should vigorously examine what actions are neccessary to upgrade the system to meet the technological advances of the threat.

Tailor the acquisition strategy to fit the project. The Patriot Project's acquisition strategy incorporated elements of an evolutionary acquisition strategy plus a P3I approach. This tailoring of strategy allows the Project Manager to incorporate new technologies into the system to counter the technological advances in enemy threat capabilities.

Develop a strong working relationship between the Project Manager and the Prime Contractor. It is imperative that strong communications exist between the project office and the contractor. The Patriot/Raytheon marriage, which has existed for nearly 30 years, has produced an unprecedented project stability. The close coordination between the Patriot Project Manager and Raytheon also contributed toward lowering defense costs, with fire unit deliveries that were under cost and on-schedule.

Consider using a multiyear procurement contract. A multiyear procurement could result in significant cost reductions in the life-cycle of a project. In the Patriot project, "a 7-year, multiyear procurement contract netted a total savings of over $445 million."[82]

Incorporate surge and wartime support provisions in contracts. Contracts should include surge options for increased production during mobilization.

B. SUGGESTIONS FOR FURTHER PATRIOT SYSTEM RELATED RESEARCH

There are a number areas within the Patriot project that are candidates for further research. Several potential topics are listed below.

How can Patriot and Theater High Altitude Air Defense system (THAADS) be integrated? This topic could explore the integration of Patriot with THAADS, an air defense system which is patterned after the Patriot and will increase the engagement capability of the system.

How should a future Patriot Advanced Capability Program be configured? Plans currently call for a PAC-4 program in the year 2001. Further research could include a comprehensive examination of the effectiveness of previous PAC programs, and

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[82]Garnett, Colonel Bruce M., Response to Peter Grier's article, "Which Service Buys Best?", Military Forum, July 1989, p. 6.

how these factors should be applied to ensure future program success.

What is the best strategy for countering future technological advances in Tactical Ballistic Missile capability? Research in this area could include an examination of stealth and ECM technology of TBMs, and what performance improvements are required to counter this threat.

What is the best strategy for deploying this system to counter the growing threat of TBM attack? This topic could examine the advantages and disadvantages of the foreign military sales of Patriot, the effects of the reduced defense budget on the project, and the effects of FMS on the defense industrial base.

APPENDIX A ACRONYMS AND ABBREVIATIONS

AAE	Army Acquisition Executive
ABT	Air Breathing Threat
ACO	Airspace Control Order
ACS	Attitude Control System
ADTOC	Air Defense Tactical Operations Center
AMC	U.S. Army Materiel Command
AMG	Antenna Mast Group
AMSAA	U.S. Army Materiel System Analysis Activity
ARM	Anti-Radiation Missile
ARU	Attitude Reference Unit
ASARC	Army Systems Acquisition Review Council
ATM	Anti-Tactical Missile
BCE	Baseline Cost Estimate
BOS	Battlefield Operating System
BTOC	Battalion Tactical Operations Center
C3I	Command, Control, Communications, and Intelligence
CARM	Counter Anti-Radiation Missile
CCB	Configuration Control Board
CDI	Classification, Discrimination, and Identification
CDR	Critical Design Review
CFA	Crossed Field Amplifier
CM	Cruise Missile
CMP	Computer Maintenance Panel
COEA	Cost and Operational Effectiveness Analysis
COIC	Critical Operational Issues and Criteria
CP	Command Post/Control Panel
CPU	Central Processing Unit
CRG	Communication Relay Group
CRLCMP	Computer Resources Life Cycle Management Plan
CTV	Control Test Vehicle
CY	Calendar Year
DAB	Defense Acquisition Board
DEM/VAL	Demonstration/Validation
DLT	Digital Link Terminal
DLTM	Digital Link Terminal Module
DLU	Data Link Upgrade
DMS	Defense Material System
DoD	Department of Defense
DPS	Defense Priorities System
DSB	Defense Science Board
DSP	Digital Signal Processor
DTC	Design To Cost
DUSA	Deputy Under Secretary of the Army

EAC	Echelons Above Corps
ECCM	Electronic Counter Counter-Measures
ECLS	ERINT Command and Launch Station
ECM	Electronic Counter Measures
ECP	Engineering Change Proposal
ECS	Engagement Control Station
EMD	Engineering and Manufacturing Development
EPP	Electric Power Plant
ERINT	Extended Range Interceptor
ERRP	Extended Risk Reduction Program
EWCC	Expanded Weapons Control Computer
FAAD	Forward Area Air Defense
FDT&E	Force Development Testing and Experimentation
FMS	Foreign Military Sales
FRP	Full Rate Production
FSC	Fire Solution Computer
FU	Fire Unit
FY	Fiscal Year
GEM	Guidance Enhancement Missile
GPS	Global Positioning System
GPU	Guidance Processor Unit
GTV	Guidance Test Vehicle
HEMTT	Heavy Expanded Mobility Tactical Truck
HFE	Human Factors Engineering
HRR	High Resolution Radar
HIMAD	High-Medium Altitude Air Defense
ICC	Information Coordination Central
IEP	Independent Evaluation Plan
IER	Independent Evaluation Review
IOC	Initial Operational Capability
IPR	In-Process Review
IPRR	Initial Production Readiness Review
IR	Infra-Red
ITOC	Integrated Tactical Operations Center
JTIDS	Joint Tactical Information Distribution System
LCS	Launch Control Station
LD	Logistics Demonstration
LE	Lethality Enhancer
LEM	Launcher Electronic Module
LLI	Long Lead Items
LRIP	Low Rate Initial Production
LS	Launcher Station
LSAR	Logistics Support Analysis Record

MANPRINT	Manpower and Personnel Integration
MC	Materiel Change
MCM	Materiel Change Management
MCP	Materiel Change Package
MD	Missile Defense
MICOM	Missile Command
MIPA	Missile Procurement Army
MMG	Multimode Guidance
MMM	Multimode Missile
MMS	Missile Management Station/Multimode Seeker
MN-ED	Materiel Need-Engineering Development
MRB	Missile Review Board
MRRB	Materiel Release Review Board
MSE	Mobile Subscriber Equipment
MSU	Mass Storage Unit
MT	Manufacturing Technology
MTBF	Mean Time Between Failure
MTTR	Mean Time To Repair
NATO	North Atlantic Treaty Organization
NAVES	Navigation Emplacement System
NCTR	Non-Cooperative Target Recognition
NFS	North Finding System
O&O	Operation and Organizational
O&S	Operation and Support
OPTEC	Operational Test and Evaluation Command
ORD	Operational Requirements Document
OSL	Out of Sector Launch
OT&E	Operational Test and Evaluation
PCoFT	Patriot Conduct of Fire Trainer
P3I	Pre-Planned Product Improvements
PAC	Patriot Advanced Capability
PA	Product Assurance
PCI	Product Configuration Identification
PCPAS	Patriot Command Post Automation System
PCU	Peripheral Control Unit
PD	Pulse Doppler
PDB	Post Deployment Build
PDR	Preliminary Design Review
PENAID	Penetration Aids
PEO	Program Executive Officer
PEP	Producibility Engineering and Planning
PID	Positive Identification
PIP	Product Improvement Proposal
PLS	Palletized Load System
PM	Project Manager
PPLI	Precise Position Location and Identification
PRR	Production Readiness Review

PTL	Primary Target Line
QRP	Quick Response Program
R&D	Research and Development
RAM	Random Access Memory
RAM	Reliability, Availability and Maintainability
RCS	Radar Cross Section
RDT&E	Research, Development, Test and Evaluation
RF	Radio Frequency
RL	Remote Launch
RLRIU	Routing Logic Radio Interface Unit
RPV	Remotely Piloted Vehicle
RRSW	Radar Resident Software
RSTA	Reconnaissance, Surveillance and Target Aquisition
RSU	Recovery Storage Unit
SAC	Senior Advisory Council
SAM-D	Surface-to-Air Missile Development
SASC	Senate Armed Services Committee
SCG	Security Classification Guide
SD	Sweepdown
SDI	Strategic Defense Initiative
SDIO	Strategic Defense Initiative Organization
SES	Senior Executive Service
SOJ	Stand Off Jammer
SRC	Senior Review Committee
SSJ	Self Screening Jammers
STAR	Systems Threat Assessment Report
TASM	Tactical Air-to-Surface Missile
TBM	Tactical Ballistic Missile
TDP	Technical Data Package
TECOM	U.S. Army Test and Evaluation Command
TEMP	Test and Evaluation Master Plan
TIWG	Test Integration Working Group
TM	Technical Manual
TMD	Theater Missile Defense
TMD	Tactical Missile Defense
TMDE	Test, Measurement, and Diagnostic Equipment
TPW	Tactical Planner Workstation
TRADOC	U.S. Army Training and Doctrine Command
TVM	Track Via Missile
TWT	Traveling Wave Tube
UHF	Ultra High Frequency
VE	Value Engineering
VHF	Very High Frequency
VHSIC	Very High Speed Integrated Circuitry
WCC	Weapons Control Computer

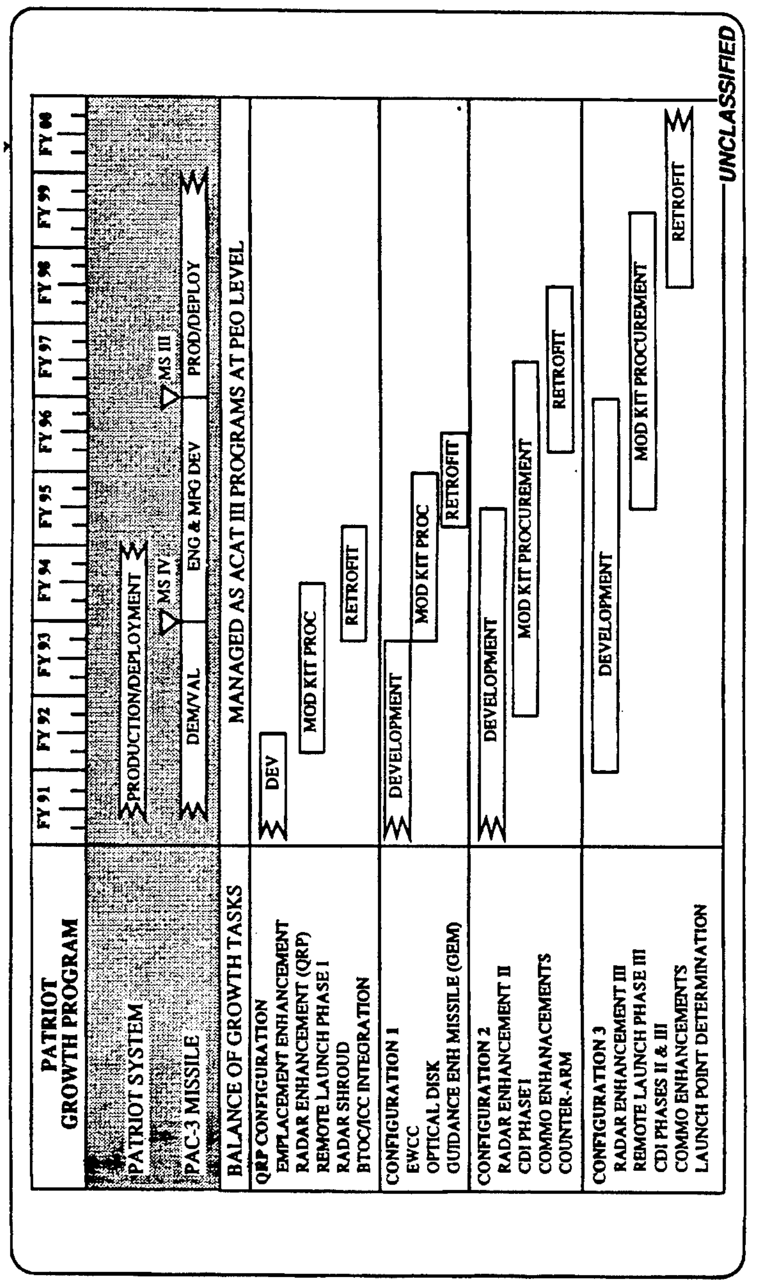
APPENDIX B PATRIOT SYSTEM DATA

DIMENSIONS:	***UNITS***	
Length:	(ft/m)	17.5/5.3
Diameter:	(in/m)	16.0/0.4
Fin Span:	(ft/m)	2.8/0.9
WEIGHTS:		
Launch:	(lbs/kg)	2,200/998
Payload:	(lbs/kg)	200/91
PERFORMANCE:		
Speed:	(mach no.)	3.0
Range:	(nmi/km)	37/69
Altitude:	(ft/m)	78,700/23,998
GUIDANCE: (type)	Command and Semi-Active Radar	
WARHEAD: (type)	Nuclear, W-85, or High Explosive	
PROPULSION:		
Model:	TX-486-I	
Number:	One	
Type:	Solid	

Source: U.S. Missile Data Book, 1994

Unclassified

APPENDIX C PATRIOT PAC-3 ACQUISITION STRATEGY



Source: Patriot Project Office, September 1993

APPENDIX D PATRIOT HISTORICAL MILESTONE DATABASE

MILESTONE	DATE	NOTE
Project Office created	Aug 65	Milestone 0
Begin Advanced Development (AD)	May 67	Milestone I
1st launch of Advanced Development missile	Nov 69	
Advanced Development completed	Feb 72	
Contract for Engineering Development (ED) awarded	Mar 72	Milestone II
SAM-D Project Office renamed PATRIOT Project Office	May 76	
1st Electronic Counter-Measures (ECM) flight test	Dec 76	
Delivery of FU-2 to WSMR	Jul 77	
Start of PEP	Oct 77	
Completion of Phase II ECM search/track tests	Dec 77	
1st MDAGS flight test	Sep 78	
Delivery of FU-3 to WSMR	Dec 78	
Delivery of FU-5 to WSMR	Feb 79	
Contract for Initial Production Facility (IPF) awarded	Mar 79	
1st msl to msl flight test (against NIKE Hercules as high altitude ABT)	Nov 79	@ WSMR
Contractor flight tests completed; Start DT/OT II testing	Jan 80	
DSARC III - Limited Production Decision approval	Sep 80	Milestone III(A)
Completion of DT/OT II testing	Dec 80	
Completion of SDDM Test Unit 1	Jan 81	
Completion of SDDM Test Unit 2	Jul 81	
Completion of SDDM Test Unit 3	Oct 81	
Full Production Decision approval	Apr 82	Milestone III
Delivery of 1st Production Set	Jun 82	
Physical Configuration Audit (PCA)	Dec 82	
Completion of Component/System design confirmation	Feb 83	
CONUS IOC (1/43 ADA; Ft. Bliss, TX) - 1st unit deployed in U.S.	Jun 83	IOC-FORSCOM
Completion of SDDM Test Unit 4	Sep 84	
FOE III sucessfully completed	Sep 84	
Conditional Material Release (USAREUR)	Nov 84	
OCONUS IOC (4/3 ADA, now 4/43; Giessen, GE) - 1st unit to GE	Mar 85	IOC-USAREUR
PATRIOT Weapon System joins NATO	Apr 85	
MOU with Japan	Nov 85	
1st Netherlands (NL) FMS delivery	Feb 86	

Source: Patriot Project Office, September 1993

PATRIOT HISTORICAL MILESTONES DATABASE

MILESTONE	DATE	NOTE
E-3 Graduation	May 86	
PATRIOT Program Directive approved	Jul 86	
IOC - TRADOC	Aug 86	
ATM PAC-2 Development Contract awarded	Aug 86	
Deployment of PDB-1 software (OCONUS)	Aug 86	
Deployment of PDB-1 software (CONUS)	Sep 86	
ATM PAC-2 msl vs LANCE msl flight test	Sep 86	@ WSMR
User acceptance 2/3 AD (E-3)	Oct 86	
Turnover of PATRIOT equipment to Germany	Dec 86	
Multiyear Production Contract awarded	Mar 87	
PDB-2 release	Jul 88	
Initial ATM capability (PAC I with PDB-2 SW)	Jul 88	
ATM PAC-2 Fielding	Sep 90	
PDB-3 QRP software release	Jun 92	
Radar Enhancement Phase II production decision (MS III) approval	Jul 92	
Quick Response Program (QRP) production decision (MS III) approval	Jul 92	

Source: Patriot Project Office, September 1993

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