Congressional Research Service

Kinetic Energy Kill for Ballistic Missile Defense: A Status Overview

Steven A. Hildreth
Specialist in Missile Defense

January 5, 2007

Congressional Research Service
7-5700
www.crs.gov
RL33240

Summary

For some time, U.S. ballistic missile defense (BMD) programs have focused primarily on developing kinetic energy interceptors to destroy attacking ballistic missiles. These efforts have evolved over 30 years and have produced a significant amount of test data from which much can be learned. This report provides a broad overview of the U.S. investment in this approach to BMD.

The data on the U.S. flight test effort to develop a national missile defense (NMD) system remains mixed and ambiguous. There is no recognizable pattern to explain this record nor is there conclusive evidence of a learning curve over more than two decades of developmental testing. In addition, the test scenarios are considered by some not to be operational tests and could be more realistic in nature; they see these tests as more of a laboratory or developmental effort. Success and failure rates (and their technical causes) have shown relative consistency through this period.

The U.S. flight test effort to develop theater missile defense (TMD) systems appears more promising. In relative terms, developmental and operational testing of TMD systems has been more successful than the NMD effort. Nonetheless, TMD systems that evolved from mature, existing ground and sea-based air-defense systems have demonstrated greater test success than other TMD programs.

How effective has the U.S. investment been in developing kinetic energy BMD systems? Observers could make any number of arguments as to what the record means and what could be done to improve the effectiveness of systems under development and of those deployed. Some observers have suggested that the 110th Congress might review the U.S. investment in the kinetic energy concept to date to determine how best to proceed with the U.S. BMD effort in the coming years. This report will be updated as events warrant.

Contents

Contacts

Introduction

The U.S. effort to develop and deploy ballistic missile defenses (BMD) based on the concept of hit-to-kill or kinetic energy kill[1] began three decades ago.[2] This effort gained momentum as the primary focus of the U.S. BMD program in the mid-1980s with the announcement of President Reagan's Strategic Defense Initiative (SDI).[3] Since that time, the United States has pursued numerous major kinetic energy BMD programs; these have produced hundreds of various flight test results. These test results and some very limited operational experience in wartime provide sufficient data for at least some conclusions regarding the decades-long U.S. investment in hit-to-kill as a concept for BMD. This overview report examines the U.S. investment in that concept, what that investment has produced, and raises various questions that might be considered. The development of BMD has shown important technological differences between efforts designed to attack and destroy short or medium-range ballistic missiles and those designed for long-range or intercontinental ballistic missiles.[4] Therefore, this report will review and distinguish between the program results of theater missile defense (TMD) and national missile defense (NMD).

CRS received historical flight test data[5] from the Missile Defense Agency (MDA) in June 2005.[6] It is important to note that for each of these flight tests there were various primary and multiple secondary objectives.[7] Such flight tests are inherently complex and relatively costly. Therefore, multiple test objectives are designed to maximize the potential benefit derived from each flight test. The determination as to whether each of these objectives was reached was made by each relevant agency or military branch. All of the references to flight test results in this report are

[1] Kinetic energy kill interceptors seek to destroy targets through a direct collision at high speeds. The force of the impact destroys the attacking missile or warhead, renders it inoperable, or diverts it from its intended target. With such an approach, a near-miss has the same effect as a large miss distance: the targeted warhead or missile is not destroyed. From its beginnings, kinetic energy kill concepts held the promise of destroying attacking missiles without the potential collateral effects of nuclear weapons explosions inherent in earlier BMD concepts and deployed systems.

[2] During the 1960s and early 1970s, the United States developed and tested a nuclear BMD interceptor capability. This system was deployed in North Dakota for a short time in 1975-1976. This system was dismantled for many reasons, including congressional and military concerns over its cost ineffectiveness in the face of a potentially massive nuclear attack, concerns over the adverse effects that nuclear detonations would have on nearby ground based BMD radars, and growing support for agreed upon limitations of U.S. and Soviet long-range nuclear arsenals. In the FY1976 defense budget, the Army initiated a program to examine alternatives to nuclear BMD. A couple years later, this effort led to the first specific kinetic energy program that sought to avoid the problems of nuclear effects on ground-based BMD interceptors by seeking to place guidance and other sensors on a non-nuclear missile interceptor itself.

[3] On March 23, 1983, President Reagan delivered a policy address announcing the establishment of the Strategic Defense Initiative (SDI) or what was quickly dubbed by others the "Star Wars" program. In his speech the President expressed his vision that the nation's scientists could develop the means of rendering "nuclear weapons impotent and obsolete." Various contemporary and historical accounts confirm that the President intended the development of U.S. BMD to be non-nuclear as well. Initial funding for the SDI program began in FY1985.

[4] For instance, some of the technological challenges are different because of where the final engagement occurs (within the atmosphere or in space) and because the closing velocities of these engagements can vary significantly (between shorter and longer range attacking missiles).

[5] There are any number of tests on systems, sub-systems and components prior to any flight test of the actual missile and interceptor itself. Pre-flight test data are not included as part of this report.

[6] MDA, "Congressional Research Service Inquiry: Flight Test Results," June 21, 2005. For Official Use Only.

[7] For illustration, an intercept flight test might have as primary objectives to: 1) demonstrate integration of system elements; 2) demonstrate sensor operations; and 3) demonstrate kill vehicle performance (intercept the target). Secondary objectives might include 1) demonstrate test monitoring; 2) provide risk reduction for future tests; and 3) collect data for model verification. Most primary and secondary objectives could be met, even if the intercept objective failed, for instance.

derived from the Flight Tests Results memorandum provided by the MDA unless otherwise referenced. CRS currently is awaiting an update of the historical flight test data from MDA, which will be reviewed and included in an updated version of this report later in 2007.

Summary of Analysis

Analysis of flight test data shows that the U.S. effort to develop, test, and deploy effective BMD systems based on this concept has produced mixed and ambiguous results. The actual performance in war-time of one kinetic-energy system currently deployed by the United States (i.e., the Patriot PAC-3) is similarly ambiguous. Further, it is not yet possible to assess the operational effectiveness the other deployed system (i.e., the National Defense System) against long-range ballistic missile threats.

Long-range Ballistic Missile Defense

The United States has pursued four major kinetic energy interceptor long-range BMD or NMD programs since the early 1980s: Homing Overlay Experiment (HOE), Exoatmospheric Reentry Interceptor Subsystem (ERIS), National Missile Defense (NMD), and Ground-based Midcourse Defense (GMD). Each of these is briefly discussed below.

The Army developed HOE in the late 1970s and early 1980s to test the viability of the emerging hit-to-kill concept. It conducted four intercept flight tests in 1983 and 1984. Three of the tests failed to intercept the intended target,[8] but the fourth was considered a success. The Army did not identify any secondary flight test objectives. Nonetheless, the nascent SDI program then viewed the single reported success as evidence of the promise of non-nuclear BMD interceptor technologies.

The technologies tested in HOE served as the basis for its successor program, ERIS. ERIS went through a lengthy development program before flight testing began in 1991 with the first of four intercept flight tests. Although the first was considered a successful intercept of the target, the following three intercept attempts through 1992 failed to destroy their intended targets.[9] Even so, officials concluded that half of the primary and secondary test flight objectives were accomplished, and that the primary BMD concept being pursued held significant promise.

The NMD program followed ERIS with a series of eight flight tests from 1997 to 2001. The first three were planned “fly-by” tests. There were no intercept attempt objectives. The first one failed to launch; however, the other two were deemed successful in their primary objectives. No secondary objectives were identified. Of the five planned intercept attempts, three reportedly intercepted their intended targets; one ended in failure because the interceptor kill vehicle did not deploy and the other failed because the on-board sensors designed to track and intercept the target failed. Officials concluded that 17 of the 20 primary objectives were met or partially met and all the secondary objectives by the planned intercept tests were met.

---

[8] Two failed tests were deemed failures because of hardware related problems. The other intercept flight test reportedly failed due to software errors in the on-board computer.

[9] Each of the three failures was due to a different reason: the interceptor failed to launch, the target failed to launch, and the third attempt missed its intended target.

The current GMD program (NMD's successor) began flight testing in 2002. Since that time six flight tests have taken place. Five of these flight tests were planned intercept attempts, with three resulting in failure to intercept.[10] Officials concluded that about 80% of the program's 40 or so primary intercept flight test objectives were met; all the secondary objectives were met fully or partially. In 2004, the GMD undertook a new configuration with a different booster and interceptor. It flew a successful integration flight test (non-intercept test) in early 2004 with all primary and secondary objectives met. This system was deployed in Alaska and California in 2004 and declared operational after eight missiles were placed in silos. Subsequently, two planned intercept flight tests in December 2004 and February 2005 failed to launch. The currently deployed system thus remains to be tested successfully against targets it might be expected to intercept. In September 2006, a successful flight test exercise of the GMD system too place. Although not a primary objective of the data collection test, an intercept of the target warhead was achieved. Flight tests whose primary objectives are intercepts were scheduled for later in 2006, but have been delayed into 2007.

Each of the four NMD programs were different, but they built on the limited successes of their predecessors. Of the eighteen or so attempted intercepts since the early 1980s, seven of them were considered successful, or roughly a 39% intercept rate in tests. Officials cited several reasons, including program hardware and software, as well as interceptor silo and target launch failures.[11] From that, there do not appear to be any recognizable patterns that emerge to account for the mostly unsuccessful history of the effort. Nor is there conclusive evidence of a learning curve, such as increased success over time relative to the first tests of the concept 20 years ago.

Program supporters can point to limited evidence that, under controlled conditions, there is reason to support the contention that kinetic energy interceptor technology for use against long-range ballistic missiles holds promise. Critics of the flight test effort to date,[12] whether they support missile defense or not in general, can raise questions about the success rate and the realism of the testing effort, given a generation of U.S. investment in its development.

Can kinetic energy interceptor technologies for use against long-range ballistic missiles be developed successfully and deployed as an effective part of the U.S. military posture? The answer appears to be ambiguous at this juncture. Can the now-deployed NMD system protect the United States from long-range ballistic missile attacks? Currently, there is insufficient empirical data to support a clear answer.

---

[10] In one test, the kill vehicle did not separate from the booster rocket, in the other two launch attempts the ground-based interceptor did not launch (once because of a software problem and more recently because of a problem with the missile silo).

[11] Although the causes of failures are varied (i.e., they include hardware, software, and interceptor and target launch problems) and do not necessarily suggest any systemic causes such as system integration, some might suggest that quality control throughout the manufacturing, systems integration and test preparation process could be a common root cause.

[12] On occasion, private organizations and others such as the Government Accountability Office (GAO) have released analyses of some of these tests. Sometimes they drew similar conclusions as those provided by the Missile Defense Agency. On other occasions, they took issue with the flight test results. Although many consider these efforts useful and constructive, because such studies lack a common framework for analysis and also do not examine all of the tests cited, their potential significance or meaning for the overall 30-year research effort is unclear. For instance, see GAO. BMD: Information on Theater High Altitude Area Defense (THAAD) and Other Theater Missile Defense Systems. GAO/NSIAD-94-167, May 3, 1994; GAO. BMD: Records Indicate Deception Program did not Affect 1984 Test Results; GAO/NSIAD-94-219, July 1994; and Federation of American Scientists, Chronology of Hit-to-Kill Missile Tests, by George Lewis, April 16, 1997, http://www.fas.org.

Theater Missile Defense (TMD)

There have been a number of major kinetic-energy TMD programs since the early 1990s: Extended Range Intercept Technology (ERINT), Flexible Lightweight Agile Guided Experiment/Small Radar Homing Intercept Technology (FLAGE/SRHIT), Navy Lightweight Exoatmospheric Projectile (LEAP), the Navy Aegis BMD, Patriot PAC-3, and Theater High Altitude Area Defense (THAAD). Each of these are briefly examined below.

The Army's FLAGE/SRHIT program conducted eight flight tests from 1984-1987 to prove the feasibility of lower atmosphere intercepts. Five of these flight tests were planned intercept attempts. From the data provided by MDA all the primary and secondary test objectives in the series were achieved. The targets included stationary targets in the atmosphere and an air-launched target. Only one target, however, was a short-range missile. The degree to which any conclusions might be drawn regarding very short-range hit-to-kill in this effort is therefore limited.

Building on the SRHIT effort, the Army's ERINT flight test program (1992-1994) conducted five flight tests. Three of these were planned intercepts; two of these three flight tests successfully intercepted their targets (the failure cited was hardware related). Despite the missed intercept, the Army concluded that all of its primary test objectives for the three tests were met fully or partially, and that all but one of the 26 secondary objectives in the three tests were met. As far as the two non-intercept flight tests were concerned, the Army determined that all of its primary and secondary flight test objectives were met.

The Navy developed its own indigenous LEAP program, which flight tested from 1992-1995. Three non-intercept flight tests achieved all primary and secondary objectives. Of the five planned intercept tests, only the second was considered a successful intercept, however. Failures were due to various hardware, software, and launch problems. Even so, the Navy determined that it achieved about 82% of its primary objectives (18 of 22) and all of its secondary objectives in these tests.

Building on some of its previous efforts in SRHIT and ERINT, the Army's THAAD program nevertheless experienced significant challenges from 1995 to 1999. After three relatively successful non-intercept flight tests (almost all of the primary and secondary test objectives were partially or fully met), THAAD failed to intercept in seven of its nine planned attempts. However, the THAAD intercept flight test program met about half of its primary and secondary objectives. Because the last two intercepts were successful (the last being in 1999), the Department of Defense and Congress agreed to further develop, but revamp, the THAAD program. The current THAAD program is a redesign of the former THAAD system. Recently, the program conducted its first flight test (non-intercept) to examine the launch, boost, and fly-out functions of the THAAD missile. MDA officials considered this test successful.[13]

The Army's Patriot (Phased Array Tracking to Intercept of Target) program has a history dating to the 1960s as an air-defense weapon. Only in the mid-to-late 1980s at the insistence of Congress was the program given a specific anti-missile role.[14] Using a focused explosive charge (non-

[13] Missile Defense Agency Bills Last Week's THAAD Flight Test a Success, Inside the Pentagon, December 1, 2005.

[14] CRS Report 91-456, *The Patriot Air Defense System and the Search for an Antitactical Ballistic Missile Defense*, by (name redacted) and Paul Zinsmeister.

nuclear and not hit-to-kill technology), Patriot PAC-2's (Patriot Antitactical Capability) 1991 Desert Storm performance remains controversial. After the war, Patriot improvements for missile defense were widely supported. Testing of the Patriot PAC-3 with a kinetic energy interceptor began in 1997. After the initial two successful non-intercept flight tests (most of the objectives were met), the Patriot PAC-3 attempted 27 intercept tests, of which 21 (about 78%) were considered successful intercepts. Additionally, some 92% of the primary intercept test objectives were met, as well as almost all of the known secondary objectives. In terms of actual wartime use, the Patriot PAC-3 was used in Operation Iraqi Freedom (OIF) in 2003, but its role was very limited (four missiles fired in two successful engagements) and thus, while suggestive of significant promise, its operational effectiveness remains uncertain based on limited empirical data.[15]

Building on its previous efforts as well,[16] the Navy (as of mid-2005) had conducted six (of seven) successful intercept tests of its Aegis BMD (or Navy sea-based) program using the Standard Missile-3 (SM-3) Block 1 missile (2002-2005).[17] The most recent test included in the data sheets provided to CRS was against a warhead target that separated from the booster rocket itself, in contrast to earlier intercept tests against SCUD-type ballistic missiles. The most recent flight test intercept attempt (in December 2006) was not completed due to technical problems aboard the Aegis cruiser involved prior to the launch of the two interceptor missiles themselves.

Primarily because of the Patriot PAC-3 flight test and operational record and the more recent Navy BMD program, the concept of hit-to-kill for TMD appears promising. Older TMD efforts were not as suggestive, and the foundation for the current THAAD program is based mostly on prior test failures. Nonetheless, because there is no flight test data yet on the current THAAD program, nothing conclusive can be said about its potential future for success. And, although the Patriot PAC-3 shows promise, some might note that the Patriot system itself has been evolving for about 40 years now. Additionally, much of the Navy infrastructure and technology supporting the Aegis SM-3 is decades old and is comparable in evolution to the Patriot air and missile defense system.

Conclusion

A central question might be: at this stage how well is the United States doing in developing effective ballistic missile defenses based on this kinetic energy kill concept? Since the announcement of the SDI program in the mid-1980s the United States has spent about $100 billion on missile defense with a primary focus on the kinetic energy or hit-to-kill concept. U.S. programs began looking at that concept a decade earlier into the mid-1970s.

---

[15] Nine Iraqi ballistic missiles were targeted by Patriot. Another six were launched but not targeted by Patriot because they were projected to land in areas that would not cause harm. The missiles that Iraq fired in 2003 were slower flying and of shorter range than those fired in 1991. The Defense Department concluded that the Patriot system successfully intercepted all nine missiles it targeted. Seven of the intercepts, however, were made with the older Patriot PAC-2 system (which still used a proximity warhead to destroy its target), while the remaining two were intercepted by the newer PAC-3. One Iraqi cruise missile reportedly eluded the Patriot radar and hit a sea wall in Kuwait City. And the Patriot system was also involved in three friendly fire incidents that resulted in the loss of a U.S. and British aircraft.

[16] The Navy program has evolved over several decades from a sea-based air defense and cruise missile defense capability to include ballistic missile defense.

[17] Sea-based Missile Defense "Hit To Kill" Intercept Achieved, News Release, Missile Defense Agency, November 17, 2005.

Supporters of hit-to-kill could argue that what the United States is striving to do has indeed proven to be challenging, but that progress is being made. Furthermore, success measured in terms of operationally effective deployed BMD systems based on this concept, loom on the horizon. They could also argue that threats posed from the proliferation of ballistic missiles and weapons of mass destruction (WMD) must be addressed by developing effective BMD systems.

Supporters and skeptics could argue the need for an independent, comprehensive evaluation of the test record to determine whether any systemic or conceptual challenges are impeding the U.S. effort. Although some defense officials have provided testimony and private and government agencies have looked in detail at a few of these tests, some might argue that a comprehensive and independent review of the entire record to date has not been undertaken and is warranted.[18]

Other observers might argue that alternatives should be pursued as a hedge against the possible failure of this concept for either NMD or TMD. Such alternatives could be military in nature, such as reducing the emphasis on BMD in favor of increased emphasis on counter-force (i.e., attacking and destroying enemy missile systems before their missile could be launched). Alternatives also could focus on other ways to mitigate ballistic missile proliferation (e.g., arms control). Some alternatives, such as a return to nuclear BMD concepts or emphasis toward more exotic technologies (e.g., lasers or weapons in space) might face opposition on political or technical grounds.

Still other observers could argue that in general the United States needs to make a more concerted effort to increase developmental testing across the board, before these systems are ready for more realistic testing regimes. They could argue that almost all the testing to date is of a developmental nature and that an operational testing regimen has not been developed, but remains essential. Only then, they could argue, could assessments to confirm the validity of the hit-to-kill concept for BMD be made with confidence.

Author Contact Information

(name redacted)
Specialist in Missile Defense
/redacted/@crs.loc.gov, 7-....

[18] One such review, performed by experts for the MDA, examined the flight test record of the NMD program and concluded among other things inadequate quality control in the flight test record was a factor. See Missile Defense Setbacks Stall Program, CNN.com, July 11, 2005.