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Report to Congressional Requesters

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OPERATION DESERT STORM

Data Does Not Exist to Conclusively Say How Well Patriot Performed

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The Honorable John Conyers, Jr.
Chairman
The Honorable Frank Horton
Ranking Minority Member
Legislation and National Security Subcommittee
Committee on Government Operations
House of Representatives

On April 7, 1992, we testified before your Subcommittee that the Project Manager's claims of the Patriot's success during Operation Desert Storm were not supported by the data.[1] The Army had also recognized the limitations of its assessment, and a few days prior to the Subcommittee's hearings, the Army revised its assessment. Among other things, the revised assessment reduced the number of engagements judged to be successful and assigned a confidence level of high, medium, or low to each successful engagement.

As you requested, we reviewed the available information on the engagements[2] that the Army is highly confident resulted in the destruction or disabling of Scud warheads. Our objective was to determine whether the Army's revised assessment of the Patriot's performance in these engagements is supported by the data.

Background

The Patriot is a surface-to-air guided missile system designed to protect U.S. forces from air strikes. Since the mid-1960s, it has evolved to defend against aircraft, cruise missiles, and, more recently, short-range ballistic missiles. The Patriot system consists of a ground radar, an engagement control station, an antenna, an electric power plant, and typically eight launchers. Each launcher contains four missiles in their individual storage-transportation launch containers.

When Iraq invaded Kuwait in August 1990, the Army deployed the Patriot to Southwest Asia to defend against the Iraqi-modified Scud missile—referred to as the Al-Hussein. The extended range of the

[1]Operation Desert Storm: Project Manager's Assessment of Patriot Missile's Overall Performance Is Not Supported (GAO/T-NSIAD-92-27, April 7, 1992).

[2]The term "engagement" means that the Patriot system detected a target, determined that the target would impact a protected area, and that a missile should be launched to intercept the target.

Al-Hussein enabled it to travel faster than the Soviet missiles against which the Patriot had been designed to defend. The Al-Hussein travels at speeds of 2,000 to 2,200 meters per second, compared with 1,600 to 1,800 meters per second for the Soviet missile.

Although the Patriot was not originally designed to engage this extended range, high-speed ballistic missile, the Army quickly incorporated changes to provide the Patriot with this capability. In less than 1 week, the Army and the prime contractor, working closely with the intelligence community, identified, assessed, and incorporated software modifications to provide the Patriot the capability to engage the faster missiles. As a result of emergency production orders, the Army was able to supply the improved missiles to all units by the time of the first Scud engagement in January 1991. After the Patriot began to engage Scud missiles, the Army made two additional software modifications. These modifications were intended to (1) increase the altitude at which the Patriot intercepted the Scud and (2) reduce the number of false targets detected by Patriot fire units.

At the time of the Iraqi invasion, there were only three of the more capable Patriot missiles with this antitactical missile capability (PAC-2) in the Army's inventory. By the end of that month, about 600 improved Patriot missiles were in Southwest Asia. This number was substantially more than what was initially planned.

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. If they impact the target's warhead region at sufficient angle and velocity, the target's warhead will detonate. 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.

The Army has issued various reports that quantify the Patriot's performance during Operation Desert Storm. According to an early report, the Patriot destroyed about 96 percent of the Scuds engaged in Saudi Arabia and Israel. As more information became known, the Army reduced its assessment to 80 percent successful in Saudi Arabia and 50 percent successful in Israel. Now, as a result of the April 1992 revised assessment,

the Army believes the Patriot was 70 percent successful in Saudi Arabia and 40 percent successful in Israel.

The Army used an improved methodology in its revised assessment of the Patriot's performance during Operation Desert Storm. The new methodology allowed the Army to (1) rank the available data according to the assessor's confidence in the data's accuracy; (2) use the ranked data to decide whether a Patriot engagement most likely resulted in a warhead kill, a mission kill,[3] or a miss; and (3) assign a high, medium, or low confidence level to the assessed outcome. The Army assessed, with either low, medium, or high confidence, 52 percent of the Patriot's engagements as warhead kills.[4]

The Army is highly confident that about 25 percent of the Patriot's Operation Desert Storm engagements resulted in warhead kills. According to the Deputy Project Manager, the assignment of a high confidence level to an engagement's outcome did not mean the Army was absolutely confident that the assessed outcome was correct. Rather, given the limited data available for assessment purposes, the Army scorers had higher confidence in the assessed outcome of these engagements than in others.

Results in Brief

The Army did not collect performance data during Operation Desert Storm that would permit an absolute determination of how many of its targets the Patriot killed or failed to kill because it was operating in a war zone rather than on a test range. As a result, the data that would be needed to conclusively demonstrate how well the Patriot performed during Operation Desert Storm does not exist and there is no way to conclusively determine how many targets the Patriot killed or failed to kill.

About 9 percent of the Patriot's Operation Desert Storm engagements are supported by the strongest evidence that an engagement resulted in a warhead kill—engagements during which observable evidence indicates a Scud was destroyed or disabled after a Patriot detonated close to the Scud. For example, the strongest evidence that a warhead kill occurred would be

[3]The Army defines a "warhead kill" as the destruction or disabling of the target's warhead. It defines a "mission kill" as an engagement during which the Patriot intercepter diverts the Scud from its intended target, thereby preventing it from causing significant ground damage.

[4]The Army has classified for national security reasons the number of warhead kills that Patriot is credited with achieving during Desert Storm. Therefore, this report provides percentages, rather than exact numbers.

provided by (1) a disabled Scud with Patriot fragments or fragment holes in its guidance and fuzing section or (2) radar data showing evidence of Scud debris in the air following a Patriot detonation. The other 16 percent of the engagements the Army is highly confident resulted in warhead kills are not supported by such evidence. In these cases, however, radar tracking data collected proves that in some cases the Patriots came close to the Scuds, but it does not prove or disprove whether the Patriots came close enough to have a high probability of destroying, disabling, or diverting them.

Assessment Had Data Limitations

According to the Patriot Project Office Chief Engineer, the same types of equipment that are used on the test range would have been required to accurately assess the Patriot's performance during Operation Desert Storm. This equipment would have included high-speed photographic equipment, portable data recorders, and telemetry equipment. Except for data recorders that captured a few engagements in Israel, the Army did not collect such information.

The Chief Engineer said high-speed photography cannot be used to collect data unless the trajectory of both the Patriot and its target are known in advance so that multiple cameras can be set up along their flight paths. He also said that this was not possible during Operation Desert Storm because obviously the time and location of Scud launches were not known in advance.

Portable data recorders had been sent to Saudi Arabia and Israel for use during Operation Desert Shield/Storm. The Project Office engineers said that during training for Operation Desert Shield, fire units in Saudi Arabia experienced system failures when recorders were attached to the Patriot's computers. Although the failures could not be directly attributed to the recorders, the brigade commander made the decision to remove them. The Israeli Defense Force, who controlled the Patriot's use in Israel, did allow recorders to be attached to some Israeli fire units,[5] but tapes exist for only a very limited number of Israeli engagements.

Telemetry data is not available from Operation Desert Storm even though the telemetry connections that would allow such information to be collected are part of each missile produced. However, according to the

[5]The Israelis also experienced one system failure after a portable data recorder was connected to a fire unit. This failure prevented the fire unit in the best position from engaging the incoming Scud

Patriot's Chief Engineer, the transmitter necessary to communicate this information to a ground recorder was not connected to each missile because of the added weight. He said that in order to accurately assess the effect the Patriot has on a target, the target must be equipped with telemetry equipment. This condition would only be found in a testing environment. If telemetry data had been collected, the scoring officials could have determined whether the Patriot (1) passed within a range where it had a higher probability of destroying the Scud and (2) had time to detonate before the Scud flew past the intercept point.

The Army obtained some data that proved helpful in assessing the Patriot's performance. The information collected by the Army included data generated by the Patriot's computers, operator reports, photographs, debris recovery, eyewitness accounts, media coverage, and various ground damage reports. Army scoring officials relied primarily upon computer-generated data and ground damage reports to support a high level of confidence that engagements had resulted in warhead kills. However, the computer data does not prove that the Patriot destroyed Scud warheads, and the ground damage searches were not sufficiently comprehensive to indicate how many warheads the Patriot killed.

Computer Data Could Not Prove Patriots Destroyed Scud Warheads

During Operation Desert Storm, the Patriot computers generated target information that was sometimes preserved on tape or in hard copy. Although this information is useful in providing information about the target and, to some extent, the Patriot interceptor, it cannot irrefutably prove that the Patriot destroyed or failed to destroy the Scud warhead.

The Army sometimes, but not always, obtained computer-generated data to show 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 (that is "engaged the target"); and
- whether the Patriot system reported that it had probably killed or failed to engage the target's warhead.

The Patriot system recorded a probable kill or an engagement failure at the conclusion of each engagement. It reported a probable kill of its target if the Patriot missiles traveled to a point in space that the system computed to be the point of closest approach to the target (the intercept point) and ceased to communicate with the ground system.

The system reported an engagement failure if the Patriot missile flew to the intercept point and continued to communicate with the ground system. When an engagement failed, the Patriot system, after a pre-set time delay, caused its missile to self-destruct.

Computer-generated data may prove that the Patriot missile came close to a Scud, but it cannot prove—even if the system reported a probable kill—that the Scud warhead was destroyed. To have a high probability of destroying a Scud warhead, the Patriot missile must detonate when it is within a few meters of the Scud. However, only portable data recorders provide a rough estimate of the distance between the Patriot and the Scud (the "miss distance") at the time of the Patriot's detonation and this information was available for only a few engagements in Israel.

Measuring miss distance is particularly important in determining whether the Patriot destroyed a Scud warhead. The Chief Engineer said that Patriot's fuze can sense its target and detonate at up to six times the required miss distance, resulting in an extremely low or no probability of kill. However, the system would still record a kill.

Also, a Missile and Space Intelligence Center engineer told us that the Scud missile exhibited some unusual reentry anomalies[6] that, according to a Project Office system engineer, could have affected the Patriot's ability to guide to its target. The Project Office engineer said that when the anomalies were severe, the Patriot might not have been able to get within the few meters where it had a high probability of destroying the Scud. Yet, if the Patriot missile's fuze detected the Scud within the recognizable distance, it could have detonated, and the system would have recorded a probable kill.

Computer-generated data also does not provide information on whether the Patriot's fuze reacted quickly enough to destroy the Scud. A Project Office engineer told us the closing velocity, or the speed at which the Patriot and Scud approach one another, helps determine whether the

[6]The reentry anomalies cannot be explained in detail in an unclassified report.

Patriot's fuze had time to arm and detonate before the Scud passed the intercept point. He said this information could be determined from recorded data. However, the project officials did not develop the information because they did not believe it would benefit the assessment process. The additional data would not have shown that the Patriot detonated sufficiently close to the Scud to have a high probability of killing it.

In response to this data limitation, the engineer said that extensive computer simulation research was used to define the air and land area that the Patriot could be expected to successfully defend. He said studies showed that the Patriots intercepting Scuds within this zone should have a high probability of fuzing at the appropriate time. However, none of the available data proves or disproves this claim.

Searches for Ground Damage Were Not Comprehensive

The Army relied heavily upon ground damage assessments in determining the high confidence warhead kills. For example, if no ground damage was found after a Scud attack and other evidence indicated that the Patriot had intercepted the Scud, the scorers assumed the Patriot had destroyed the Scud in the air. If a Scud was found with Patriot fragments or fragment holes in its guidance and fuzing section, scorers assumed the Patriot had disabled the Scud. The scorers assumed the Patriot had missed the Scud if there was evidence of a warhead explosion on the ground. However, since all ground damage assessments were not equally comprehensive, the absence of identified ground damage could be a misleading indicator of a warhead kill.

A number of sources reported ground damage during Operation Desert Storm. The Army used the following reports in its revised assessment process to help determine whether the Patriot had destroyed or damaged a Scud warhead: a compendium of ground damage included in messages obtained by the Missile Space and Intelligence Center;[7] investigative teams' reports; a Ballistic Research Laboratory ground damage assessment; and an Israeli Air Force ground damage assessment.

However, according to the Assistant Deputy Project Office Manager, while the Israelis conducted a coordinated, comprehensive ground search effort, the U.S. government did not make any single group responsible for ground

[7]The message traffic consists of a collection of ground damage reports transmitted from various organizations in Southwest Asia to the communications center at Redstone Arsenal, Alabama.

damage searches in Saudi Arabia. Therefore, the extent and reliability of ground search efforts in Saudi Arabia—and consequently its reports—were seriously limited.

Message Traffic

Intelligence Center officials informed us that they had little confidence that the reports they had collected contained descriptions of all ground damage that had occurred or that all damage had been accurately portrayed. They said that many of the reports had been based on interviews with Saudi citizens—rather than with trained experts—who had observed or had been present during attacks but had not observed ground damage.

Intelligence Center officials said that the reports were not meant to provide performance data and do not provide conclusive proof that Scud or Patriot damage did or did not occur. They added that one of the agencies that generated ground damage reports from interviews recommended caution in using these messages, stating that they provided preliminary, often unverified, and sometimes contradictory information. The agency also said some messages included what are now known to be erroneous or misleading statements.

Investigative Team Reports

During Operation Desert Storm various individuals had attempted to locate impact points of Scuds or Scud debris. These individuals, whom the Army termed "investigative teams," viewed debris and craters. They tried to determine whether the debris was a part of a Patriot or a Scud and analyzed the size of the craters to determine whether they most likely resulted from a Scud warhead or some other Scud component, such as a fuel tank. However, these individuals did not investigate all engagements, and they did not prepare written reports at the time of the events. Rather, they prepared their reports from memory at the request of the Patriot Project Office months after the actual events occurred.

Ballistic Research Laboratory's Analysis

Our review of the Ballistics Research Laboratory's ground damage assessment revealed serious limitations in the Laboratory's analysis. For example, the assessment contained data on only about one-third of the Saudi engagements, and the data was collected by one engineer days or weeks after the Scud impacts occurred. The assessment also relied heavily upon photographs and interviews with military personnel assigned to the Patriot units. This methodology was necessary because by the time of the engineer's visit to the damage sites, the craters had often been filled and missile debris removed.

Strongest Evidence Exists for Relatively Few Engagements

While the assessment data collected by the Army cannot provide absolute proof that the Patriots killed Scuds, post-intercept observable data provides the strongest evidence that a warhead kill has occurred. For example, strong evidence that a Patriot has destroyed or disabled a Scud would include (1) a ground damage report that a Scud had been recovered with Patriot fragments or fragment holes in its guidance and fuzing section or (2) radar tracking evidence that the Scud has experienced a dramatic slowdown and that debris was present after a Patriot intercept.

Based on our analysis, this type of evidence of a warhead kill exists for about 9 percent of the engagements that the Army believes resulted in warhead kills. For one such engagement, data generated by the Patriot system computer and a unit report provide proof that the Patriot system detected, engaged, and intercepted a Scud, and ground damage reports showed no damage was reported that could be linked to the engagement. However, in this case, the Patriot's computers also provided information about the events that had occurred after intercept. Data shows that after the Patriot detonated, the system no longer saw a target of ballistic missile speed, but rather many small targets moving at much slower speeds. These are the characteristics of debris and stronger evidence for the contention that the Patriot did destroy the Scud.

In another engagement, an operator reported that the Patriot had intercepted and probably killed an incoming Scud. This report alone would be weak evidence of a kill. However, an Army warrant officer actually viewed the Scud on the ground and saw the Patriot's fragment holes in the warhead skin. His statement provides a high level of confidence that the Patriot disabled the Scud.

According to a Project Office engineer, if the Patriot missile was highly accurate, evidence of the Patriot's success would probably not be preserved. For example, if a Scud was blown into very small pieces, the Patriot system would probably not be able to track the resulting debris, and radar tracking evidence of the Patriot's success would not be recorded. However, since extensive ground searches that would have ensured finding the debris were not conducted for most of the engagements, conclusive evidence is not available to prove or disprove this theory.

Engagements Supported by Lesser Evidence

Lesser evidence exists for the other 16 percent of the engagements that the Army classified as high confidence of a warhead kill. For several of the Army's high confidence warhead kills, for example, the Army used (1) computer-generated data to support its determination that a Scud had been detected, engaged, and intercepted and (2) ground damage reports that showed no ground damage relating to these engagements.

The computer data proves that the Patriot missiles came close to the Scuds, but it does not prove or disprove whether the Patriots came within the few meters necessary to have a high probability of killing the Scuds. Neither does the Army know whether the Patriots' fuzes armed and detonated before the targets passed the intercept points.

In addition, no evidence exists to clarify what happened to the Scuds after the intercept occurred. Radar tracking data does not indicate debris in the air, and since the ground damage reports for these events did not result from a systematic search for ground damage, they do not provide a high level of confidence that all ground damage was reported or that reported damage was accurate.

Scope and Methodology

We discussed the Army's methodology for the revised assessment with Army officials to determine how the Army assigned a high, medium, or low confidence level to the Patriot's Operation Desert Storm engagements that the Army believes resulted in warhead kills. For the Patriot engagements that the Army was highly confident had resulted in warhead kills, we examined documents—such as recorded Patriot computer data and ground damage reports—that the Army had used to make this judgment. We obtained clarifying information through discussions with officials from the Patriot Project Office, the U.S. Army Missile Command's Research and Development Engineering Center, and the Missile Space and Intelligence Center, all located at Redstone Arsenal, Alabama. We also discussed ground damage information with individuals at the Ballistic Research Laboratory, Aberdeen, Maryland; the Training and Doctrine Command's Patriot System Manager's office, Fort Bliss, Texas; and the Eleventh Brigade, Riyadh, Saudi Arabia.

We conducted our review from April to July 1992 in accordance with generally accepted government auditing standards.

As requested, we did not obtain fully coordinated Department of Defense comments on this report. However, we discussed our findings with the

Patriot Project Manager and other officials at the Patriot Project Office. They generally agreed with our findings.

As you requested, we plan no further distribution of this report until 30 days from its issue date. At that time, we will send copies to other interested congressional committees, the Secretaries of Defense and the Army, and the Director of the Office of Management and Budget. Copies will also be made available to others on request.

Please contact me at (202) 275-4141 if you or your staff have any questions concerning this report. Other major contributors to this report are listed in appendix I.

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