

Why were Scud casualties so low?

Steve Fetter, George N. Lewis and Lisbeth Gronlund

Patriot missiles were returned to the Gulf last week. But they were not the reason for the unexpectedly low casualty rate when Saddam attacked Israel with Scud missiles in 1991.

IRAQ fired more than 80 modified Scud missiles at Israel and Saudi Arabia during the Persian Gulf War in 1991. These attacks caused 31 deaths, numerous injuries and substantial property damage. With the exception of the Scud that hit a barracks in Dhahran, Saudi Arabia, and killed 28 US soldiers, however, the number of deaths and serious injuries caused by each missile appear to be much lower than one would have expected based on the results of previous ballistic missile attacks. The relatively low casualty rate has been cited by several analysts as evidence of the success of the Patriot missile defence system¹⁻⁵. Others have argued that the same casualty data suggest that the Patriot may not have been very successful⁶.

What effect did Patriot have on casualties during the Gulf War? Here we show that the publicly available data do not support claims that Patriot played a significant role in preventing casualties or damage to buildings in Israel. (We focus on Israel because relatively little data are available from Saudi Arabia.) Why, then, were casualties so low in Israel? To answer this question, we review the effects of previous ballistic missile attacks on cities and discuss various factors that may account for the lower casualty rate in Israel.

Role of Patriot

The Scud attacks on Israel began on the morning of 18 January 1991, but the first Patriot battery did not become operational until after 11 Scuds had fallen. Of the 38 Scuds that reached Israel, 27 were fired after Patriot was operational; of these, 17 were engaged by Patriot missiles⁷. Most or all of the other ten Iraqi missiles fell in areas not covered by the Patriot batteries deployed near Tel Aviv and Haifa.

According to the US Army's most recently revised estimates of Patriot effectiveness, of the 17 engagements in Israel, only 40% were successful, and the Army had "high confidence" in only 40% of its claimed successful engagements in Israel and Saudi Arabia⁸. Thus, of the seventeen Scuds engaged, at most seven were intercepted, and in only three of these cases does the Army claim high confidence (assuming equal confidence levels in Israel and Saudi Arabia).

The Army claims have been challenged by independent analysts^{9,10}. But

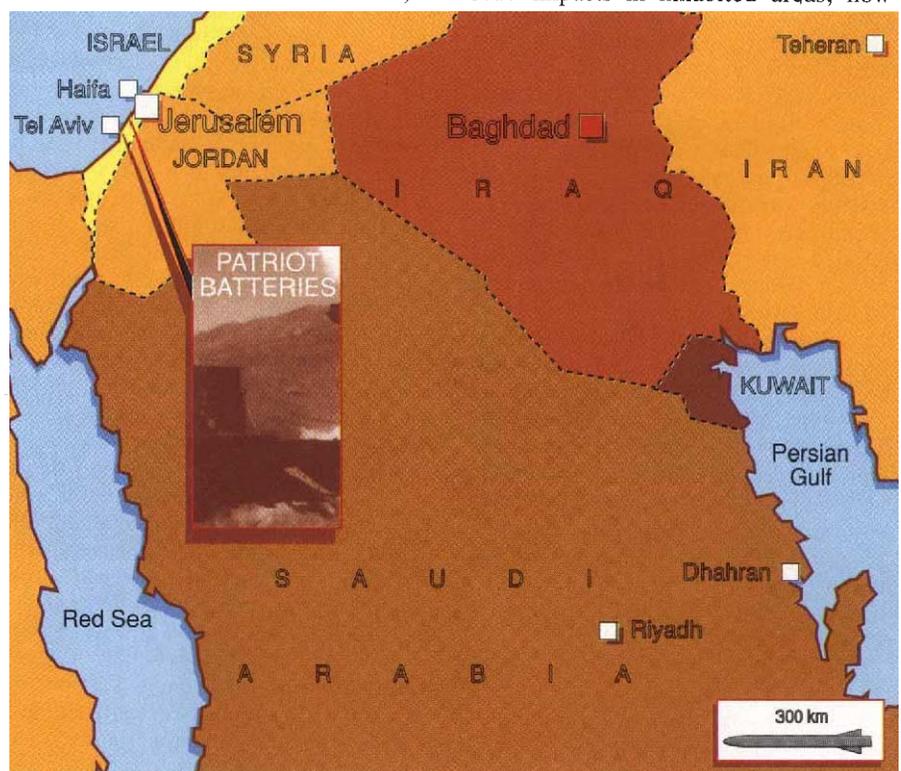
even if we accept the Army's data, Patriot would have reduced the expected casualty rate by no more than 16 to 40%. Moreover, any damage prevented by successful intercepts must be weighed against the damage caused by the four Patriot missiles that struck the ground and exploded in Israel^{2,11}, as well as by the debris from intercepted Scuds and from Patriots that detonated above cities. Because of the lack of accurate track data on the Scud and Patriot missiles, the effect of Patriot in preventing casualties and damage in Israel will never be known with any certainty. Given that large statistical fluctuations would be expected in the damage from small numbers of inaccurate ballistic missiles armed with conventional warheads, any effect that Patriot may have had on casualties or damage is lost in the noise.

Casualty and damage statistics before and after Patriot deployment support this conclusion. The 38 modified Scud missiles fired at Israel directly killed two people and injured about 230 more. Almost all the injuries were light, with only ten classified as moderate and one as severe^{12,13}. Of the direct casualties, 52

occurred before Patriot was operational (4.7 per missile) and 179 after (6.6 per missile)¹². All but two of the 179 casualties after Patriot was operational were caused by Scuds that fell in defended areas. Both deaths and most or all of the serious injuries occurred during the period of Patriot defence.

The situation with respect to property damage is more complicated. Theodore Postol has published a translation of a compilation of damage to buildings that appeared in the Tel Aviv newspaper *Ma'ariv*⁶. According to *Ma'ariv*, 2,797 apartments suffered damage before Patriot (254 per missile) and 9,029 after Patriot was operational (334 per missile). Much of the damage to apartments was very light (such as broken windows). If only apartments that were seriously damaged or destroyed are counted, the figures are 40 per missile before Patriot and 34 after Patriot.

Thus, although serious damage to apartments appears to have decreased slightly after Patriot became operational, light damage, injuries and deaths all increased. Given the small number of Scud impacts in inhabited areas, how-



Map of the regions discussed here. Two of the Patriot emplacements defending Israeli targets are shown.

IMAGE UNAVAILABLE FOR COPYRIGHT REASONS

Mary Evans

a warhead with 160 to 190 kg high explosive¹⁷, including the kinetic energy of the missile, which was reduced by its tendency to break up during re-entry, the total energy released on impact would have been equivalent to no more than 250 kg TNT, compared to 900 kg TNT for the V-2 (ref. 14). Because the area subjected to blast damage scales as the yield to the two-thirds power, the lethal area created by the impact of the modified Scud was 0.43 times that of the V-2.

Thus, scaling for differences in population density and warhead yield, the expected casualty rate in Teheran was three times greater than that in London during the Second World War, which can be estimated as 14 deaths and 35 serious injuries per Scud impact. This estimate is in good agreement with the available (albeit sparse and unreliable) information about casualties in Iran cited above. We stress, however, that a detailed comparison with the London experience has not been done because we lack information about many important aspects of the attacks on Teheran (civil defence, construction practices, and so on). As we shall see in the case of the attacks on Israel, such factors can have a significant effect on casualties.

Scud attacks on Israel

As noted above, the 38 modified Scud missiles fired at Israel resulted in 2 direct deaths, 11 serious injuries, and about 220 minor injuries. The number of Israeli casualties produced by the modified Scud missiles seems remarkably low compared with previous ballistic missile attacks. In fact, the total number of deaths and serious injuries in Israel was less than that caused by just one average missile impact in London or Teheran.

As discussed above, it is necessary to account for differences in population density and warhead yield when estimating casualties. Most of the casualties in the Gulf War occurred in the Tel Aviv metropolitan area, which had a population density of about 70 per hectare in 1991 (ref. 14). As was the case in London and Teheran, many people left Tel Aviv during the missile attacks. Although this evacuation was widely reported in the press, its extent is difficult to estimate, especially as many of the evacuees left only at night, returning to their jobs in the morning. In the absence of better information, we assume the same fraction of evacuees as in London, which gives a night-time population density about 1.6 times that of London during the missile attacks.

The modified Scud missile used against Israel was apparently the same as that used against Iran, and it appears that essentially all the missiles launched by Iraq during the Gulf War also broke

Bomb damage by V-2 rocket to brick-row houses in Tottenham, north London, 1944.

ever, these differences are not statistically significant. We can conclude only that the available data do not support the hypothesis that Patriot had a significant effect on casualties or damage.

Previous ballistic attacks

A review of the effects of previous ballistic missile attacks helps to put the Israeli casualty rate in perspective. Before the 1991 Gulf War, ballistic missiles had been used extensively in war only three times: the Germans launched more than 3,000 V-2 missiles against urban British and European targets during World War II; Iraq and Iran together launched nearly 1,000 missiles against each other's cities during the 1980–88 Persian Gulf War; and the Kabul government fired more than 2,000 Soviet-made Scud missiles against Mujahideen guerrillas in the Afghanistan civil war. In all cases the missiles were armed with conventional high-explosive warheads. Detailed information on casualties and physical damage is available only for the V-2 attacks on London.

V-2 attacks on London. From September 1944 until March 1945, Germany launched about 3,000 V-2 ballistic missiles at targets in Britain and continental Europe. Of the approximately 1,400 V-2s fired against Britain, 518 fell in the London civil defence district. In addition, nearly 10,000 V-1 cruise missiles were fired against London. Even though most of the V-1s malfunctioned or were destroyed by British defences, about 2,420 fell on London.

Although the V-2 and the V-1 warheads had nearly equal explosive yields and created roughly equal amounts of property damage per missile¹⁴, each V-2 impact in London resulted in an average of 4.8 deaths and 11.7 serious injuries, compared to 2.2 deaths and 6.3 serious

injuries per V-1 impact¹⁵. The lower casualty rate for the V-1 was due primarily to the fact that people in the target area could hear the V-1 approach and could take cover before its warhead exploded, while the V-2 gave no warning of its approach¹⁶.

Scud attacks on Teheran. Only limited information is available on casualties and damage from the Iraqi Scud attacks on Teheran during the so-called "War of the Cities". A total of 189 modified Scud missiles fell on six different Iranian cities from 29 February to 20 April 1988; 135 of these landed in Teheran¹⁷. On 4 April, after about 125 missiles had fallen, it was reported in Iran that 1,150 people had died and 4,000 had been injured from the missile attacks. Some foreign analysts believe that Iran under-reported casualties to minimize civilian panic, and estimate that 2,000 people died¹⁸. Thus, about 10 to 15 people were killed and at least 30 injured per missile impact.

If we assume that the circumstances of the Scud attacks on Teheran were similar to those of the V-2 attacks on London, we need only modify the London casualty estimates to account for differences in population density and warhead yield to estimate the expected casualty rate in Teheran. The population densities of Teheran and London before the Scud and V-2 attacks were about 300 and 43 per hectare, respectively; the available information suggests that roughly 20 per cent of the population was evacuated during the attacks in both cases¹⁴. All else being equal, a given warhead would on average kill and injure about seven times as many people if targeted against Teheran rather than London under the circumstances described here.

The modified Scud reportedly carried

up on re-entry. After applying the appropriate scaling factors for population density and warhead yield to the casualty rates from V-2 attacks on London, one would expect about 3.3 deaths and 8.1 serious injuries per Scud impact in Tel Aviv. Thus, the actual number of deaths that resulted from the 38 missiles launched against Israel was more than 60 times less than what might have been expected based on this straightforward extrapolation from the experience in London. This simple analysis, however, omits several important factors.

Warning time. A major difference between the missile attacks on London and Teheran and those on Tel Aviv was that (except in the first two attacks) the Israeli population generally had a few minutes warning time in which to take cover. This was because the United States shared satellite information on Scud launches with Israel. We can account for this very roughly by comparing the casualty rate for the V-1 attacks, for which there was some warning, with that for the V-2 attacks, for which there was no warning. After correcting for its slightly smaller yield, the death rate from V-1 attacks was 0.5 times that from the V-2 attacks (0.58 for serious injuries). Thus, taking into account warning time in addition to population density and warhead yield, the expected rates are reduced to 1.6 deaths and 4.7 serious injuries per missile impact in Tel Aviv.

Another factor that may have reduced casualties is that virtually all the missile attacks on Tel Aviv occurred at night, whereas the attacks on London occurred throughout the day. Thus, most Israelis were at home during the attacks, and on hearing the warnings simply had to go into interior rooms to obtain a degree of shelter.

Inaccuracy of the modified Scud. A key factor in limiting the damage to Israel was that most of the modified Scud missiles did not strike populated areas. According to a study of Israeli casualties, only six warhead explosions caused direct casualties¹³.

The basic Scud-B is so inaccurate that, at its maximum range of 300 km, at least half the impacts would fall more than 1 km from the target¹⁹. Moreover, the pressure the Iraqis were under to launch the missiles quickly, combined with the modifications made to the missile by Iraq to more than double its range, undoubtedly led to a substantial decrease in the accuracy of the missile.

It is difficult to determine the number of Scud impacts in Israeli cities because Israeli censorship regulations did not allow the release of the precise locations of Scud impacts. In the 15 attacks involving a single Scud missile, however, there is little difficulty in identifying the cases in which a warhead detonated in a

populated area: three such warheads exploded in populated areas in or near Tel Aviv; the other 12 warheads presumably fell in uninhabited areas, were duds or were destroyed by Patriot missiles.

It is more difficult to sort out what occurred in the four multiple Scud attacks in which a total of 23 missiles were launched at Tel Aviv and Haifa. The first two attacks occurred before Patriot was operational. Seven missiles were fired at Tel Aviv and Haifa at about 2 a.m. on 18 January 1991, and four missiles were fired at Tel Aviv at about 7 a.m. on the following day. Robert Stein, manager of Advanced Air Defense Programs for Raytheon (Patriot's manufacturer), states¹ that most of these missiles "were not on target, and only very few fell on Tel Aviv". Taken literally, this means that no more than

destroyed by Patriots and, as noted below, at least one of the warheads that landed in Tel Aviv was a dud.

Blast-resistant dwellings. One Israeli study of the Scud casualties concluded that the most important factor in reducing casualties was the construction practices used in modern Israeli apartment buildings¹³. The multi-storey apartment buildings erected in Tel Aviv over the past 30 years are constructed with reinforced concrete columns, beams and floors^{13,20}. The reinforced concrete elements prevented buildings close to Scud detonations from collapsing and burying their inhabitants. On the other hand, when missiles struck near older, unreinforced masonry buildings, these were often completely demolished, with the roof and walls collapsing.

By contrast, the typical London dwell-

AP

IMAGE UNAVAILABLE FOR COPYRIGHT REASONS

Patriot missile keeping watch over Tel Aviv in January 1991.

five Scuds were on target; as discussed below, at least one of these did not explode. A Pentagon briefing on 25 January 1991 also implied that no more than five of these missiles landed in populated areas and caused damage¹⁴.

The other two multi-Scud attacks occurred during the period of Patriot defence: seven missiles were launched on 25 January and five the next day. In the first attack, only two clearly identifiable explosion sites in populated areas were reported: one in a residential neighbourhood and one at a school. The only impact reported in a populated area in the second attack occurred on a deserted beach in Tel Aviv.

Thus, it appears that only about 10 Scud warheads exploded in populated areas in Israel. What happened to the other 28? Some landed well short of Tel Aviv or in the Mediterranean Sea. It is possible that others landed in unpopulated areas in or near Tel Aviv and Haifa but went unreported by the news media. An anonymous Pentagon scientist was reported⁷ as saying that Scuds not engaged by Patriot "either fell in the sea or out of range of the Patriot batteries, near towns in the West Bank or in the Negev desert". One study noted¹³ that of the missiles launched against Israel, "a number fell in the sea or exploded in the air". Finally, some Scuds may have been

ing was the brick-row house, which often collapsed from the blast of nearby V-2 explosions. The limited data available on the effects of V-2 missiles on reinforced concrete buildings in London indicate that the area of structural damage is roughly eight times smaller than for brick-row houses¹⁶. Because deaths and serious injuries are due primarily to the structural collapse of buildings, Israeli construction practices were probably a significant factor in reducing the casualty rate relative to that in London.

Dud warheads. Some Scud warheads simply failed to detonate. In the second attack on Israel, a warhead penetrated several floors of a building before coming to rest in a ground-floor jewellery shop, where it was recovered intact²¹. There were also reports that one or more of the missiles fired at Israel did not carry explosive warheads²². Given the ample evidence that many of the warheads that landed in populated areas did explode, however, the fraction of duds was probably small.

Civil defence. Most of the beneficial effect of civil defences has already been accounted for in the discussion of warning time and construction techniques. Israel devoted substantial resources to rapid rescue efforts, and several people were reportedly rescued from collapsed buildings. But it is unlikely that Israeli

IMAGE
UNAVAILABLE
FOR COPYRIGHT
REASONS

Scud launched from Iraq hits Tel Aviv at night in January 1991.

efforts were much better than those of the British rescue services, which had experienced several years of German air attacks by the time of the V-1 and V-2 launches. Thus, civil defence probably played a minor role in reducing the casualty rate relative to that in London. **Coincidence.** Substantial statistical fluctuations are expected in attacks involving only a small number of inaccurate ballistic missiles with small damage radii. Because only about ten warheads detonated in Israeli cities, luck must have played a crucial role in determining the overall casualty rate. Indeed, there is considerable anecdotal evidence that good fortune was important in reducing casualties in Israel. Of the warheads that detonated in Israeli cities, one hit the only empty lot in a densely populated neighbourhood²³, three others hit a park, a factory and an unfinished shopping mall during the night. Two Scuds landed near unoccupied buildings: an underground bomb shelter at a municipal centre and a school. Even when Scuds severely damaged occupied buildings, casualties were remarkably low: a missile that landed in an alleyway between several apartment buildings and caused one building to collapse killed only one person, and an attack that destroyed a two-storey house and severely damaged

several others also killed only one person; two people reportedly survived only because they disobeyed government instructions and went to their basement bomb shelter.

Conclusions

Given the number of missiles fired, casualties in Israel at first appear to be very low compared with what could have been expected on the basis of previous ballistic missile attacks. But several characteristics of the modified Scud helped to limit casualties, most notably the inaccuracy of the missile (only about one-quarter of the missiles detonated in populated areas in Israel), together with its small warhead, its break-up on re-entry and an unknown but probably small number of dud warheads.

Several other factors seem to have been important in reducing casualties. The difference in the V-1 and V-2 casualty rates suggests that the warning time provided by US launch-detection satellites reduced casualties by a factor of two. In addition, coalition air attacks forced Iraq to launch missiles after dark, when most Israelis were at home.

Taken together, these factors allow us to estimate, based on the London V-2 experience, that 16 deaths and 47 serious injuries would have been expected from

the roughly 10 Scud detonations in Israeli cities, excluding casualties that may have been caused by the 4 Patriot impacts. Two deaths and eleven serious injuries actually occurred. Much of this apparent discrepancy may be due to Israeli construction practices, which prevented the collapse of heavily damaged buildings. As noted above, the limited data from London indicate that the area of destruction for reinforced concrete buildings was about eight times smaller than that for brick-row houses.

Given the significant statistical fluctuations that would be expected in a casualty rate based on such a small number of explosions, these factors could account for the observed casualty rate in Israel. However, anecdotal evidence also suggests that luck helped to reduce casualties. As illustrated by the Scud that hit the barracks in Dhahran and killed 28 soldiers, shifting the impact point of a single missile by tens of metres could have changed the casualty statistics dramatically, given the small number of warheads that detonated in Israeli cities.

The available evidence does not support claims that the Patriot missile defence system significantly reduced casualties in Israel. While Patriot might have destroyed some warheads that would otherwise have caused casualties, the available data contain no evidence for a net reduction in casualties or damage due to Patriot.

Several important lessons can be drawn from the experience of the Gulf War. The widely held belief that ballistic missiles are themselves weapons of mass destruction is simply incorrect, as demonstrated by this as well as by past episodes. It is the nature of the warhead, not the mode of delivery, that counts. Even attacks with conventional warheads could be far more lethal. If a few missiles had struck crowded buildings, or if the missiles had been more accurate or had carried larger warheads, or if the attacks had taken place during the day rather than during the night, the number of deaths could have been many times greater. Finally, advance warning of missile attack, which in this case was made possible by satellites, can save lives by allowing people to shelter or to take other evasive action. □

Steve Fetter is in the School of Public Affairs, University of Maryland, College Park, Maryland 20742, USA. George N. Lewis is in the Defense and Arms Control Studies (DACS) Program, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139, USA. Lisbeth Gronlund is at the Union of Concerned Scientists, 26 Church Street, Cambridge, Massachusetts 02238, USA, and is a research fellow at DACS. This article is based on a more detailed paper (ref. 14.)

1. Stein, R. *Int. Security* **17**, 200 (1992).
2. Zraket, C. *Defense News* 31 (9 December 1991).
3. Pfaltzgraff, R. L. Jr *Wall Street J.* A20 (8 April 1992).
4. *Detroit News* 8 (13 April 1992).
5. Boot, M. *Christian Sci. Monitor* 9 (23 September 1992).
6. Postol, T. A. *Int. Security* **16**, 119–171 (1991–92).
7. Schmidt, E. *New York Times* (Int. edn) A8 (31 October 1991).
8. Schmidt, E. *New York Times* A11 (8 April 1992).
9. US General Accounting Office. *Operation Desert Storm: Data Does Not Exist to Conclusively Say How Well Patriot Performed* (GAO/NSIAD-92-340, September 1992).
10. Lewis, G. N. & Postol, T. A. *An Evaluation of the Army Report "Analysis of Video Tapes to Assess Patriot Effectiveness"* (MIT Defense and Arms Control Studies Program, September 1992).
11. Kaplan, F. *Boston Globe* 1 (5 May 1991).
12. Bleich, A. et al. *J. Am. med. Ass.* **268**, 613–615 (1992).
13. Karsenty, E. et al. *Israeli J. med. Sci.* **27**, 603–607 (1991).
14. Lewis, G. N., Fetter, S. & Gronlund, L. *Casualties and Damage from Scud Attacks in the 1991 Gulf War* (MIT Technology, Defense and Arms Control Studies, January 1993).
15. Dunn, C. L. *The Emergency Medical Services* **1**, 174; 179 (HMSO, London, 1952).
16. US Strategic Bombing Survey, *Physical Damage Division V-Weapons in London* Report No. 152 (January 1947).
17. Carus, W. S. & Bermudez, J. S. Jr *Jane's Soviet Intelligence Review* **2**, 242–248 (1990).
18. Bierman, J. *Maclean's* 34–36 (18 April 1988).
19. Zaloga, S. *Int. Defense Rev.* **11**, 1427 (1988).
20. Rudge, D. *Jerusalem Post* 8 (22 February 1991).
21. Brinkley, J. *New York Times* 1 (20 January 1991).
22. *Flight Int.* 13 (13–19 March 1991).
23. Chartrand, S. *New York Times* A7 (19 January 1991).