Chapter Eleven: Missile Systems And Proliferation

Iraq successfully used long range missiles, but such missiles were conventionally armed and lacked accuracy and lethality. Iraq did not deliver weapons of mass destruction. Iraq had massive numbers of chemical weapons, and had used them in previous conflicts, but never used chemical weapons during the Gulf War. Iraq's biological warfare capabilities were uncertain and untried. It did not yet have nuclear weapons and could not pose a threat of nuclear escalation.

At the same time, Iraq was developing a massive capability to produce and deliver such weapons. UN experts have estimated that Iraq had 52 missile storage, assembly, and maintenance facilities, 13 facilities associated with biological weapons facilities, 48 facilities associated with chemical weapons, and 21 facilities associated with nuclear weapons at the time of Desert Storm. Even these totals may be an undercount, and they symbolize the fact that the growing risks posed by proliferation is one of the most important lessons of the Gulf War.

There is no way to be certain what would have happened if Iraq had used weapons of mass destruction. It is possible to speculate about the war fighting impact of proliferation, the value or non-value of missile defenses, the need for civil defenses, the future of counter-proliferation, and the importance of biological warfare. The fact remains, however, that such speculation cannot be based on what actually took place. As a result, this chapter concentrates on six major topics: The Coalition's readiness for chemical and biological warfare, Iraq's use of missiles, the Western counter-missile effort; Iraq's preparations to use chemical weapons; Iraq's capability to use biological weapons, and the state of Iraq's nuclear weapons effort and its possible implications.

Coalition Readiness for Chemical and Biological Warfare

There is no doubt that Iraq's decision not to use chemical or biological weapons was fortunate for the Coalition. Many of the Coalition forces were unprepared for such war, and this was as true of US forces as those of the other members of the Coalition.

The US did rush in chemical defense forces. During the first phase of Desert Storm, it deployed two Army chemical battalion headquarters, seven heavy decontamination companies, seven dual-purpose (decontamination and smoke) companies, four nuclear-biological-chemical (NBC) reconnaissance platoons, and several chemical defense staff augmentation units. With the build-up of additional ground forces, it deployed another two Army chemical battalion headquarters, five heavy decontamination companies, three smoke generation companies, five dual purpose companies, and additional staff augmentation. This build-up eventually gave the US a total of 45 CBW defense units, with a total of 6,028 soldiers and more than 450 vehicles for reconnaissance, detection, decontamination, and smoke generation.[1]

The US had protected some of its major combat equipment against chemical and biological warfare contamination before the war. The Army had protected 24 of 40 armored systems, but only two US systems had the overpressure systems needed to provide a high degree of protection. The Navy had protected seven types of ships, but this included a total of 33 out of 450 ships. These ships only had the lowest Level I degree of protection. The USAF had not protected any of its aircraft, although it had some decontamination capability and the training and equipment to operate in a limited chemical environment.[2]

However, many US chemical and biological defense capabilities were marginal at best. The US had little time-urgent surge capability to produce nerve gas injectors and chemical protective suits.[3] It had shortages of chemical warfare suits and modern gas masks, and had had serious problems in chemical defense capability since at least the mid-1980s.[4] US forces were not properly trained for chemical warfare when the Gulf War began, and equipment was lacking for many reserve units and even active support units in Europe. War reserves and prepositioned stocks were well below authorized levels.

The US Army was the central manager for buying chemical defense equipment for the US armed services, but it had failed to meet requisitions of one to four million modern chemical warfare suits between FY1988 and the beginning of the Gulf War, and its prepositioned reserves had been inadequate for five years. The US had to draw on all its world-wide reserves to transfer more than 1.1 million chemical protection over-garments.

The US Army eventually obtained 300,000 more new suits by mid-February, but US manufacturers experienced serious problems in producing modern suits.[5] Roughly 20% of the US personnel that were issued protection suits during the Gulf War were forced to use an older suit with less protection and endurance. None of the suits produced in the US were light enough for desert warfare, and manufacturers also failed to come close to meeting their promised delivery schedules for surge orders placed after Iraq invaded Kuwait. As a result, the Marine Corps had to independently purchase 208,915 light weight suits from a foreign manufacturer after the Gulf war began because of the problems in the Army program.[6]

Similar problems existed in the US gas mask program.[7] The inability of the original manufacturer to meet production schedules had badly delayed delivery of the more modern M-40 and M-42 gas mask. The original contract had to be terminated for default in January, 1990 -- after the manufacturer produced defective equipment and met only 1% of his required delivery schedule. Two new manufacturers were selected, but they too experienced problems. They had not delivered any masks as of August, 1990 -- although deliveries were supposed to have begun in September, 1989.

As a result, almost all US troops were forced to wear obsolescent M-17 and M-25 gas masks -- with fit, respiration, canister change, and communications problems. Even then, refitting of M-17 masks has to be stepped up to 5,000 per week to meet the demand for Desert Storm.[8] The M-17 mask and its filters also exhibited a high failure rate during Marine Corps testing, and would probably have killed many soldiers to which it was issued, if it had had to be used in combat.[9]

US decontamination capabilities were ineffective. Its equipment consisted of the M-258A1 individual decontamination kit, small sprayers like the M-11 or M-13 to decontaminate vehicles and weapons, and the M-12A1 power driven decontamination apparatus mounted on a 5-ton truck. A lighter M-17 decontamination system was also delivered to some forces. There was insufficient water to supply such systems, however, and the M-12A1 and M-17 systems were unreliable, produced insufficient water pressure, and lacked adequate spare parts. The M-17 had regularly failed after extended use in training or trials.[10]

Both the Department of Defense and the GAO concluded after the war that US biological and detection capabilities were inadequate.[11] The US had the capability to detect most chemical agents, and deployed more than 1,300 chemical agent monitors (largely M-236 chemical detector kits and M-8A1 automatic chemical agent alarms).[12] However, the US had no long range detection gear, and virtually no gear to detect biological agents. Even US chemical detection gear presented problems because it was so prone to false alarms that this sometimes led the operator to ignore the warning. This equipment also experienced frequent battery failure because of high temperatures, and the maintenance load of this and most other chemical defense equipment was much heavier than anticipated -- particularly in terms of air filter changes.[13]

The only US standoff detection system, the XM-21, was still under development and had a relatively short range. Only 10 were available in theater during Desert Storm and these systems still had significant technical problems. The XM-21 only met the tests required to qualify for low rate production nearly four years after the war was over.[14]

These problems, and the lack of a dedicated CBW reconnaissance vehicle, led the US to obtain Fox (Fuchs) chemical detection vehicles from Germany. The Fox was a six-wheeled armored vehicle with over-pressure protection, and was equipped with mass spectrometers and a fully integrated CBW detection. warning, and communication capability. It could analyze air and collect water, soil, and vegetation samples for later analysis, and had the range (500 miles) and speed (65 MPH) to keep up with maneuver forces. As a result of its experience with these vehicles, the US Army decided to procured more advanced versions (XM-93 and XM-93E1) after the Gulf War, with enhanced chemical detection capability and a greatly enhanced biological detection capability.[15]

The US was totally unready for biological warfare. Its protective gear was ineffective, its antidotes and treatment capabilities were limited in coverage and effectiveness, and it had negligible detection capability. The US issued detection kits that could detect two biological agents, but these kits only functioned after the user had already been exposed to the agent for 13 to 24 hours and had no value as warning systems.[16] The US had no options in responding to Iraq's biological program other than trying to destroy delivery systems, providing an immunization program useful only against one agent -- Anthrax, hoping that chemical protection gear would provide some help, and retaliating by escalating its attacks on Iraq.[17]

Under these conditions, it is not surprising that the threat of Iraqi chemical and biological warfare affected some aspects of US operations. The US changed its scheduling for off-loading and moving its combat units during Desert Shield to reduce potential exposure to chemical and biological attacks, which caused some confusion both loading and off-loading ships. The US rushed in additional chemical defense capabilities from all over the world, and seek additional equipment from Germany. Even then, it was only able to fully equip the portion of its land force that crossed into Iraq and Kuwait, and was never able to deliver enough water into the forward area to carry out effective decontamination. Problems occurred with gas masks, torn suits, detection gear, and atropine shots.

Planning for casualties presented problems in terms of treatment facilities, and forced the US to create parallel evacuation and triage networks to keep chemical or biological casualties from contaminating assets, and provide facilities that were designed to deal with conventional wounded.

The threat of chemical and biological warfare required a major training effort at a time when other training activities had high priority. Commanders and troops had to be trained to decide on what level of protection to use, and then how to compensate for the resulting loss of effectiveness. These training problems were compounded by US reliance on National Guard and reserve decontamination units, many of which proved to have low proficiency and training performance.[18]

The US also had to train new detection teams and some 1,500 medical personnel to treat chemical wounds.[19] It had to integrate the chemical detection systems and Fuchs vehicles that it obtained from Germany into its force structure, and redirect its intelligence and command staffs to focus on indicators of Iraqi use of chemical weapons. It had to acclimatize forces to the debilitating effects of using chemical protection gear, and train and prepare teams for decontamination operations.[20]

The threat of chemical warfare also posed serious problems in terms of human factors. US trials found that units lost approximately 50% of their effectiveness in full MOPP gear without any chemical attack. Even without decontamination activity, the threat of chemical warfare meant that water had to be increased above the nine quarts per day provided for drinking water in peacetime, and two quarts per hour provided in action. Full mission-oriented protection posture (MOPP-4) gear meant wearing a full protection suit, mask, rubber gloves, and rubber boots that required additional water.

The US had no way of providing full protection for large areas involving high levels of activity. This involved key targets like Dhahran and Riyadh, as well as a number of assembly areas and air bases.[21] The US did attempt to develop an active defense capability by creating an extensive air defense system, screening the border, and deploying the Patriot. However, this system was scarcely leak proof, and the Patriot's limited anti-tactical ballistic missile defense capabilities were still in development at the time the Gulf War began.

More broadly, the US had no clear counter-proliferation doctrine, and only limited counter-proliferation capability. As will be discussed shortly, it was not able to destroy Iraq's chemical weapons stockpiles or Scud missile launch capability, and had uncertain targeting capability even against major Iraqi production capabilities. The US also had no clear doctrine regarding retaliation and extended deterrence. If the US had plans to retaliate against Iraqi use of chemical and biological weapons by changing its strategic bombing effort, these plans have not been disclosed. The US had overwhelming nuclear superiority, but rejected the use of nuclear retaliation. The US had rejected the use of biological weapons in the mid-1970s, and had only limited capacity for chemical retaliation.

This fundamental lack of US readiness for chemical and biological warfare is a major lesson of the Gulf War, and has helped make counter-proliferation a top US defense planning priority since the war. It has led the US Army -- the central manager of US nuclear-biological-chemical defense efforts -- to establish a Chemical and Biological Defense Agency in October, 1992, and an Army Research Laboratory effort to improve chemical and biological defense capabilities. It has led the US Army to recommend new lightweight protection clothing and defensive equipment, the full integration of CBW protection and cooling systems into combat vehicles, and the procurement of stand-alone transportable collective protection shelters. It has also led the US Army to recommend massive improvements in biological warfare defense capability, including detectors, vaccines, and protective equipment.[22]

However, the US was just beginning to develop detailed plans to implement its counter-proliferation policy in the mid-1990s. It also was still developing systems for biological detection, stand-off nuclear-biological-chemical (NBC) detection and multi-agent chemical detection. It had only limited NBC reconnaissance capability, limited chemical monitoring capability, and only manual warning and reporting capability. Much of its protection gear was not fully compatible with its night vision equipment, it had only limited biological vaccines, it still used highly corrosive decontaminants, and a wide range of other -practical war fighting problems.[23]

Allied capabilities were mixed, but all Coalition countries had similar or worse problems. Britain had limited chemical defense capabilities at the time of the Gulf War. It treated chemical protection gear as a "system", its S-10 gas mask was significantly superior to the US M-17, or M-25, and its gear was relatively modern. At the same time, it too had no real biological defense capability, and its chemical agent monitors were no more sophisticated than US detection systems. Like the US, it obtained the German Fox vehicle to help compensate for major weaknesses in its ability to conduct maneuver dominated chemical and biological warfare.[24]

The defenses of France and the Arab members of the Coalition were limited largely to personal protection gear, some of which was inadequate. No other Coalition country had more effective defenses against biological weapons. Iraq's attacks on Israel forced Israel to rapidly disseminate chemical defense gear, but Israel too had only limited biological detection and defense capabilities.[25] Although Israel could pose the risk of nuclear retaliation, it still had to hastily improvise missile defenses with the Patriot.

Given this level of overall Coalition capability, it is interesting to speculate as to what would have happened if Iraq had waited to invade Kuwait until it had acquired some nuclear weapons, had deployed an effective force of chemically armed long range missiles, and had deployed a full range of advanced chemical and biological munitions. It is far from clear that the Western or Arab states that made up the Coalition would have reacted to the build-up of Iraq's capabilities by deploying effective defenses and offensive capabilities in time to fight a different kind of war. The risks to the West in deploying sufficient ground and air forces would have been far greater. So would the risks to Saudi Arabia, Bahrain, and the other Southern Gulf states in providing the ports, bases, and staging areas used by Coalition forces. It is at least possible that the war would never have taken place.

Iraq's Use of Long Range Missiles

In order to understand Iraq's use of missiles during the Gulf War, it is necessary to understand the nature of Iraq's missile forces, and some of the key limitations of those forces. While Iraq is sometimes seen as having a highly advanced missile capability, this was anything but the case.

The Capabilities of the "Scud B"

All of Iraq's missiles were variations of the Scud, a missile derived from the German V-2 of the 1940s, and which the Soviets first deployed in the 1960s. The Scud has many limitations by modern standards. All of the various models are single stage systems using liquid propellants and which have limited growth and modification capability. While the missile has been steadily improved with time, even the later variants are very large relative to their range and payload, have limited accuracy, require complex pre-surveying to achieve this accuracy, and normally have a complex and unwieldy set up and take down process.[26] These factors made the Scud obsolescent by Soviet standards by the mid-1970s, and it was being replaced by the SS-23 before the INF Treaty led to all such systems being withdrawn from Soviet forces.

Two slightly different modifications of the missile seem to have been sold to the Third World. One is about 11.25 meters (36.9 feet) long and 0.85 meters (2.8 feet) in diameter. The other is 11.58 meters (37.9 feet) long and 0.91 meters (3.0 feet) in diameter.[27] The smaller missile is normally said to have a range of 300 kilometers (186 miles) and the larger missile to have a range of 450 kilometers (279 miles). Both systems have a minimum range of about 160 kilometers. There is some evidence that the smaller missile loses accuracy and reliability at ranges over 280 kilometers.[28]

These missiles can be launched from fixed sites, towed trailers, and a now obsolete tracked IS-3 chassis. The launchers used in Iraq were normally MAZ-583 vehicles that act as a transport-erector-launcher (TEL). The MAZ-583 is an eight wheeled, four axle vehicle. The missile normally rides flush inside the vehicle, and can look like a large fuel truck or tractor trailer from a relatively short distance. It is normally supported by the ZIL-157 propellant tanker, and a mobile command and control van. Both of these vehicles look like commercial vehicles. There is also a special trailer for reloads which is attached to a ZIL-157 vehicle, and crane mounted on a Ural-375 truck to move the missile on the launcher. A Scud fire unit is normally supported by an End Tray weather radar, which tracks wind patterns using a radiosonde balloon, but this radar does not have to be collocated with the missile. All of these vehicles can easily be confused with commercial vehicles at a distance.[29]

NATO normally refers to the smaller missile as the SS-1 Scud A, and the latter missile as the SS-1 Scud B, but these NATO designations bear no relation to the Soviet name for the missile, which the Soviet Union first introduced as the "R-7". The terminology that NATO uses in describing the Scud is also confusing because some sources have referred to Iraqi and North Korean modifications of the Scud as "Scud Cs," although this was the name originally given to a developmental Soviet-made longer range variants of the missile. Most importantly, the NATO designations disguise the fact that both basic variants of the Scud have undergone a steady series of refinements and modifications. This series of modifications is reflected in the fact that the Soviet designation for the larger missile is now the 17E. Similar improvements have taken place in the associated support equipment and warheads.

Another problem affecting much of the reporting on these systems lies in the fact that the reporting focuses solely on the missile body or booster, but ignores the technical details of the warhead. The warhead, however, is a critical aspect of the Scud's performance, and there are many variations in terms of type and fusing options. These variations include a dummy, conventional high explosive, chemical, biological, nuclear, and possibly a developmental cluster or bomblet warhead.

The Scuds in Soviet inventory were designed primarily to kill area targets using warheads with nuclear weapons with yields in excess of 100 kilotons, and Soviet forces employed the Scud almost exclusively as a theater nuclear system. In contrast, the export versions of the Scuds given to countries like Iraq only have conventional warheads. There is no definitive evidence that the former Soviet Union, or any of the Warsaw Pact countries, have ever provided developing countries with the designs for chemical warheads, and the former Soviet Union never seems to have transferred any technology relating to the biological and nuclear warheads to even its Warsaw Pact allies.[30] This places important technical limitations on the ability of Third World countries to use the missile, since modern nuclear, chemical, and biological warhead technology is more sophisticated in many ways than the rest of the Scud missile design.

Most experts believe that Iraq only had the "Scud B," or modifications of the "Scud B," in inventory at the time of the Gulf War. This version of the missile weighs about 6,370 kilograms (13,888 pounds) fully loaded, and has a 800 kilogram (1,760 pound warhead). This missile has about 4 tons of propellant and a powered flight time of about 70-75 seconds. It does not have a sophisticated guidance system. It follows a calculated ballistic course to target, which is corrected by a simple strap-down inertial guidance system. Course correction is by adjustment of the refractory jet vanes in the motor exhaust. The cruciform long-chord cropped tail fins located only at the base of the missile only provide stability.

Modification of the Scud is difficult. The large surface area of the missile cannot be changed without changing accuracy. Attempting to burn additional propellant affects the ability of the jet vane control system to function, and the sharply pointed war head is critically shaped and balanced. Any change can cause the missile to wobble, tumble, or break up on reentry, which also affects accuracy. The reliability and accuracy of the regular "Scud B" was also achieved by extensive practical testing, recalibration, and modification. Like the rest of the missile, the "Scud B's" guidance technology and engineering base does not permit easy reengineering and modification in ways that fundamentally affect its accuracy and reliability.

For the missile to be accurate, it must be fired from a pre-surveyed site against a target whose coordinates are exactly known according to a common grid. The targeting problem is more serious than it may appear because the world is not perfectly round, and locating launch site and target to precisely the same standard of measurement requires both sites to be measured using a common system. This precision is as not necessary with nuclear warheads, but is vital when conventional warheads are aimed at small area targets. It is easy to introduce errors of several hundred meters with normal location systems.

Winds are a problem at the launch point, and to a lesser extent on reentry. The missile accelerates relatively slowly during its initial flight up through the atmosphere, and radiosonde techniques are needed to measure winds, and the guidance must be recalibrated accordingly. It takes about 40 minutes to fully complete the combination of exact siting and wind calibration needed for maximum accuracy with a highly trained crew.

The reentry problem is different. The missile travels so fast that air resistance can affect its accuracy. At the same time, any problem in the shape and weight balance of the warhead or missile can cause tumbling or break-up. This does not affect the performance of Soviet systems, which used well tested nuclear warheads. It does, however, present another major modification problem for nations like Iraq in modifying either the missile body or warhead. Even minute shifts in weight and sizes could sharply degrade accuracy and reliability, and make them difficult to predict, unless the modification was refined on the basis of extensive range testing.

Iraq's Search for More Advanced Missiles

The only recorded use of the Scud in combat before the Iran-Iraq War occurred in the October 1973 War. Egypt fired three Scuds at Israel, all of which missed their targets. However, both Iran and Iraq made use of the "Scud B" in the Iran-Iraq War. Iran initiated the use of Scud attacks in 1982, and had the advantage that Iraq's capital was within Scud range of Iranian territory. Iraq retaliated by launching "Scud B" missiles against Iranian population centers to the rear of the battlefield, but could not attack key targets like the Iranian capital of Tehran with the "Scud B".[31] Tehran is about 510 kilometers from the Iraqi border -- about 220 kilometers beyond the range of the "Scud B".[32]

Iraq reacted with a massive effort to acquire the longer-range missiles that it needed to attack targets deep in Iran. There is still considerable uncertainty as to exactly how Iraq got the technology to modify its Scuds. Various sources have claimed that Iraq received Chinese, Egyptian, French, German, and/or Soviet help, and technicians and parts from other nations may have been involved. The main research for the Iraqi effort seems to have occurred at a facility at Taji, missiles were modified at a facility in the Nasr missile factory, and mobile launchers were produced at a facility near Daura.[33]

Iraq successfully tested its first new variant of the "Scud B" -- called the Al Hussein -- in August, 1987.[34] The precise range-payload capabilities of this missile cannot be determined as a result of the attacks made during either the Iran-Iraq or Gulf Wars because the Iraqis regularly moved the missile launch sites during their attacks. It seems to have about 25% more fuel than the regular "Scud B," or about 5 tons of propellant.

The US government has released data indicating that the missile has a range of about 650 kilometers (375-400) miles, and a circular effort of probability (CEP) of 1,500-3,000 meters.[35] Other sources provide different data. One Israeli source estimates that the Al-Hussein has a maximum range of 600 kilometers, a warhead weight of 300 kilograms, a flight time of 420 seconds, and a CEP of around 1,700-2,300 meters.[36] Other experts indicate that it has a range of 375 miles and a warhead weight of only 250 pounds.[37] Still other sources report that the Al-Hussein utilizes a reduced payload package (985 to 190 kg) to effect a 100% growth in range to 600 km (328 NM). Some sources also indicated before the Gulf War that the Al Hussein had re-fire times of 60 minutes versus 160 minutes for the earlier model Scuds.[38]

In any case, the Scud does not have a high level of accuracy. Further, the term CEP only describes the distance from the target where 50% of the missiles fired (that function perfectly through launch and are perfectly aimed) will land from the target. The remaining 50% land substantially further away from the target -- but the miss distance is difficult to predict. Real world accuracy is also reduced below the CEP because missile and target locations are rarely known with perfect precision, and many firings involve at least some malfunction within a missile, which further degrades operational accuracy.

The Al-Hussein did, however, give Iraq a missile that could reach Tehran and Qom from positions south of Baghdad, and Iraq fired an average of nearly three Al-Hussein's a day. It and fired 135-160 missiles at Tehran between February 29 and April 18, 1988, and a total of around 200 Al Husseins at all targets in Iran.[39] Other sources indicate that Iraq launched a total of approximately 360 "Scud B's and Al-Hussein missiles at Tehran and other Iranian cities during the "War of the Cities."[40]

Some experts suggest that these missiles often broke up during the Iraqi attacks on Iran. One suggests that the missile tended to wobble during its ascent phase, where the impact of the wobble is reduced by the fact it is still under power and rising, and then experiences growing problems from this wobble as it renters the atmosphere at high velocity and without power. He also feels that the center of gravity is less forward in the Al-Hussein, which can lead to substantial wobble that makes the missile break up at high altitudes during reentry -- generally at altitudes of 15-20 kilometers.[41]

Iraq developed more advanced missiles after the August 1988 cease-fire in the Iran-Iraq War. Iraq tested a missile on April 25, 1988, which was initially called the Al-Abbas. This system was later renamed the Al-Hijarah or "stones," after the stones used by the Palestinian children and teenagers in the Intifada.

The Al-Hijarah missile was a still further modification of the "Scud B," with additional fuel tanks that were relatively crudely welded into the main body. This type of modification may account for the fact that Iraqi missiles proved to be unstable during the Gulf War and often broke up upon reentry. Ironically, this break up also created the equivalent of a "decoy capability" because the Patriot could not separate the radar signature of the Scud warhead from other missile fragments.[42]

By 1990, the Al-Hijarah matured into a system whose performance was initially estimated as having a maximum range of 700-900 kilometers, a 100 to 300 kilogram payload, a flight time of 540 seconds, with an operational CEP at maximum range of 2,500 to 3,000 meters.[43] Iraq did not demonstrate this long maximum range during the Gulf War, and some experts now feel that the missile's range may actually be below 800 kilometers, with a payload of around 200 kilograms, and an operational CEP of 3,000 meters.[44]

Iraq also quietly tested and deployed chemical warheads for its regular and longer-range Scuds.[45] The timing of Iraq's chemical warhead tests is uncertain, but UN inspection efforts later showed that Iraq had binary chemical warheads at the time of the Gulf War.[46] These warhead designs were not particularly reliable or effective. They had crude aluminum welds, some shape and loading stability problems, and relatively crude technology for disseminating the chemical agent as the warhead reached its target. There is also some question about their range, and the amount of chemical agent that could be delivered, since even the Soviet-designed VX chemical warhead had 555 kilograms of active agent for a warhead weighing 985 kilograms. The chemical payload of a smaller warhead drops sharply as a proportion of total weight because the mechanism needed to disperse the agent which cannot be reduced in the same proportion. However, the Iraqi chemical warheads could still have been used as terror weapons.

Iraq was seeking even more advanced missile systems at the time that it invaded Kuwait, and spent billions of dollars between 1980 and 1990 on missile development and production facilities, and on facilities to develop and produce weapons of mass destruction to be delivered by missiles. As part of this effort, it funded a massive missile research and development establishment. Iraq established research links with Argentina and Egypt, and joined them in a project called Badar 2000. This project was supposed to turn a large Argentine weather rocket called the Condor -- which Argentina had developed in the late 1970s -- into a two-stage solid fuel long-range missile, with a payload of 450 kilograms, and a maximum range of 950 kilometers.

While Egypt and Argentina eventually canceled their work on the Badr 2000, Iraq tried to continue the project on its own.[47] According to one report, it set up facilities to produce cases and nozzles at the Dhu al-Fiquar factory at Fallujah, the solid fuel mixing and casting at the Taj al-Ma'arik factory near Latifyah, and motor assembly and testing at the Al-Yawm al-Azim factory near Musayib. The project was managed largely by Iraqis, using a wide range of foreign experts, and some technical workers hired in Pakistan.[48] Iraq may, however, have had to abandon the Badr 2000 before the war. Argentina's guidance system technology was inadequate, and had lagged far behind its development schedule. Egypt had not met a single goal for its share of the project, and little serious attention seems to have been paid to warhead design.

Iraq had little success with other efforts to modify the SA-2, SA-3, and SA-6 surface-to-air missiles for use in the surface-to-surface role. Such modifications have serious inherent accuracy and range-payload problems. Iraq's Sa'ad 16 facility was not able to operate much of the equipment that Iraq had imported to build more advanced warheads when the Gulf War began, and Iraq was still seeking carbon fiber warhead technology and manufacturing equipment to improve its warhead capabilities. Iraq's reliance on relatively crude metal warheads helps explain the failure of many of the extended range Scuds that it launched against Israel and Saudi Arabia, as well as some of the problems in the design of its chemical warheads.[49]

Iraq did, however, work on other systems that might have given it improved missile capabilities during the next few years. Iraq hired a separate 23 man missile technology development team from Brazil. This team was led by retired Major General Hugo de Olivera Piva, the ex-director of Brazil's Aerospace Technology Center. Piva headed the effort to convert Brazil's Sonda IV space rocket into a missile large enough to carry a nuclear warhead. This team helped Iraq develop two related systems: the Al-Abid and the Tamuz.

The Al-Abid first attracted world attention on December 5, 1989, when Iraqi TV showed the launching of long-range booster at the Al-Anbar space research center, which it claimed to have reached a range close to 1,500 nautical miles.[50] According to some reports, this three stage missile was built with the assistance of the Canadian "Super Gun" designer, Dr. Gerald Bull; as well as with the Brazilian team. The Al Abid seems to have been a 48 ton missile whose main booster used a cluster of five Scuds. The second stage used two Scuds, and the third stage was of Brazilian design. While the primary reached an altitude of 12,000 meters, the other two stages either failed to separate, or may not have been activated during in the test. Nevertheless, the test showed that Iraq might eventually be capable of launching a satellite into orbit or firing much longer range missiles.[51]

On December 14, 1989, Iraq announced it had developed another new missile called the Tamuz 1. It claimed that it had tested the missile twice, and that the launches had reached ranges of up to 1,500 kilometers.[52] The Tamuz was also being built with Brazilian assistance, but -- in spite of Iraqi claims -- it does not seem to have been tested and may still have been in the developmental stage when the war began. The Tamuz appears to have been a three-stage, liquid fueled, 48-ton missile similar to the Al-Abid. It may have used the same booster system -- with five al-Abbas boosters in the first stage, one in the second stage, and a third stage with a 750 kilogram payload.[53]

Some experts feel that the Tamuz could have had a range of roughly 2,000 kilometers once it was fully developed. Others experts believe that a range of 1,250-1,500 kilometers was more likely once a military payload and guidance package was added. Such a missile would be very complex, involve a great deal of launch preparation and launch time, and require large fixed facilities. It would, however, have been the first Iraqi missile with sufficient range-payload to deliver a large nuclear weapon, or large chemical or biological weapons payload, against any target in Israel and Iran from launch sites deep in Iraq.[54] UN inspections after the Gulf War confirm that Iraq had been actively working on nuclear warhead designs for such missiles.[55]

Iraq continued to improve its production and test facilities for long-range missiles shortly before it invaded Kuwait. In April, 1990, information surfaced that Iraq might be setting up a new missile test range in Mauritania in West Africa. Such a test range would have given Iraq the ability to test missiles in excess of 1,000 miles -- tests that were impossible in Iraq without crossing international borders -- but the existence of such a range was never confirmed. In July, 1990, it became apparent that Iraq had quietly sought to buy titanium furnaces from the US. Such furnaces can be used to manufacture a number of lightweight titanium missile parts, including advanced nose cone designs for Warheads.[56]

Iraq made claims to have completed further missile developments after it invaded Kuwait. On October 9, 1990, Saddam Hussein announced that Iraq had developed a new missile that could hit Israel. Some experts now believe that Saddam was talking about modifications to Adnan 2 drone, but Iraq never used this system against Israel and no new ballistic missile was ever found.[57] The timing of the Iraqi announcement also indicates that it may have been nothing more than a propaganda ploy. Saddam Hussein made the announcement one day after a major clash between Israelis and Palestinians at the Temple Mount in Jerusalem, and at a time when Saddam Hussein was trying to exploit and weaken Arab support for the Coalition.[58]

While any estimates of the performance of Iraq's deployed missiles are highly controversial, Table 11.1 provides a rough comparison of the characteristics of Iraq's missiles at the time of the Gulf War:[59]

Table 11.1

Comparative Performance Of Iraqi Surface-To-Surface Missile Systems

	"Scud B"	Al-Hussein	Al-Hijarah	Tamuz/ Al Abid
Date first appeared	3Aug 87	18Mar88	7Dec89	-
Number of stages	1	1	2	3
Diameter (meters)	0.884	0.884	0.884	-
Length (meters)	11.7	12.55	13	-
Weight (kilograms	6,300	7,340	34,500	-
Range (kilometers)	280	600	750	1,200-1,500
Chemical-Warhead (kilograms)				
Total weight (Kg.)	985	190	220	-
Weight of agent (Kg.)	555	107	-	-
CEP (meters)	900	3,000	3,000-5,000	5,000+
Flight time (minutes)	6.0 - 6.5	8.0 - 9.0	10-12	-
Flight mach		4.0	4.0	4.0 -
Fuse	Variable proximity	Variable proximity	Variable proximity	-

Source: Adapted by the author from material in US Department of Defense, Conduct of the Persian Gulf War: Final Report, Department of Defense, April, 1992, pp. 16-18 and working paper by Dick Pawloski.

Iraq's Missile Activity During The Gulf War

When the Gulf War started, Iraq had up to 1,000 Scuds of all types, including several hundred extended-range Al Hussein and Al Abbas missiles. These missiles were deployed in a brigade-sized formation of three to four regiments based on a Soviet model. This unit seems to have been headquartered near Taji, north of Baghdad, which became the center of Iraqi Scud missile operations during the Iran-Iraq War.

Many US experts initially felt that Iraq's missile forces would be easy to target. They estimated that Iraq had 24-36 Soviet-supplied mobile missile launchers at the time the war began, and that Iraq's surface-to-surface missile brigade had an active strength of three to four regiments of three launchers each, had a deployable strength of only 9 to 12 launchers.[60] However, Iraq may have had more launchers than the US estimated. It was deploying new transporter-erector-launchers (TELs) called the Al-Walid or Al-Nida, which it had displayed at the Baghdad International Arms Exhibition in 1989.[61] Some experts feel that at least one unit with Iraqi launchers became operational before the war, and supplemented Iraq's standard Soviet-designed MAZ-543 launchers.[62]

In any case, Iraq proved far less predictable in using its forces than many intelligence experts predicted. It had begun to make major changes in the deployment of its Scud forces long before its invasion of Kuwait, and had expanded its missile deployments to cover its western as well as its eastern borders. In the process, Iraq established a large number of pre-surveyed sites.

In February 1990, US intelligence detected Iraqi construction of new fixed missile launcher complexes in Western Iraq. Press reports differ over the size of these complexes. Some indicate that there were five complexes with 28 operational launchers -- although such counts seem high. In any case, Iraq could use them to launch the 600 kilometer range Al-Hussein to reach the Israeli cities of Tel Aviv and Haifa, Israel's nuclear facility in Dimona, and targets throughout Syria and in much of Turkey.

Some reports also indicate that Iraq deployed from 12 to 18 Al-Abbas missile launchers to three fixed sites in southern, western, and northern Iraq in March, 1990. According to UN reports, the sites included 28 fixed launchers in western Iraq, with other fixed sites near Taji, Baghdad, and Daura.[63] If these reports are accurate, the northern and southern sites would have given Iraq the ability to strike deeper into Iran, and the Western and southern sites gave Iraq the ability to strike at other targets and provide coverage of targets in Israel, Syria, and Turkey.[64]

One source indicates that the site nearest to Israel was close to the H-2 Airfield in western Iraq, on the road between Iraq and Jordan, and had six launchers oriented towards targets in Israel or Syria. Still another report indicates that Iraq had nine prepared launch sites for its regular Scud Missiles with 62 launch positions, although several normally did not have launchers deployed.[65]

The construction of these fixed sites led US intelligence and Coalition air planners to focus on them as major targets. This proved to be a mistake. While Iraq probably felt the fixed sites could be used to launch several volleys of missiles before they could be struck by Coalition or Israeli aircraft, it must have realized they would be detected by US satellites and could be struck immediately in the event of war. As a result, it seems likely that Iraq, at most, planned to use its fixed launchers to create a first strike or "launch under attack" capability to fire chemical weapons against Israel, and to then shift to mobile launch units and treat the fixed sites as the equivalent of decoys.

In any case, it is unclear that Iraq made a serious move to deploy significant numbers of missiles to its fixed sites during Desert Shield. Iraq may have felt that such deployments would simply lead to preemptive attacks, and result in the loss trained personnel. Iraq did, however, disperse some of the equipment for its mobile missile units after the beginning of Desert Shield, expanded its survey activity to create more pre-surveyed launch sites in the south. It began to actively redeploy its mobile Scud units into the field at some point in late 1990 or January, 1991, and deployed fueled Scuds into positions where they could fire "volleys" of Scud missiles at the start of the Coalition attack.

The exact range of support equipment that Iraq deployed with its mobile missile units is uncertain. Iraq is known to have used the Soviet "End Tray" meteorological radar associated with the FROG 7 and "Scud B" in some of its missile deployments, and the UAZ-452T support vehicles. It is not known how effective this equipment was in supporting long range fire using the Al-Hussein and Al-Hijarah. Iraq also deployed at least battalion sized protection units with its launchers to guard against raids by infiltrators and special forces. [66]

The dispersal of Iraq's mobile missile units near a wide range of potential launch sites made them very difficult to target. The large number of presurveyed sites allowed Iraq to create broad launch zones and disperse its missile units in a large amount of territory. Its TELs and support vehicles were difficult to distinguish from commercial vehicles without extensive reconnaissance. Iraqi forces had also developed the capability to hide their TELs and missiles with camouflage, in civil buildings, underpasses, and in other places of concealment, and deployed some highly accurate decoys.

Once the war began, Iraq used mobile launch units in both the western and southern parts of Iraq to hit targets in Israel and Saudi Arabia.[67] The pattern of these launches is shown in Table 11.2. Iraq launched its first two Scuds against Israel late on the afternoon of January 17th. The first strike on Saudi Arabia took place on January 18th.

One of the early strikes against Israel hit Ramat Gan, a suburb of Tel Aviv, and had a major political impact. While the blast did not produce any direct deaths, several Israelis died of heart failure, ninety-six people were wounded, and some 1,700 apartments suffered at least some form of superficial damage.[68] Iraq's Scud strikes might well have caused large scale panic, and brought Israel into the war, if it had not been for the fact that the Coalition immediately responded by launching a massive "Scud hunt" in the form of strike aircraft, the US had not rush Patriot units to Israel, and if the Patriot air defense system had not initially seemed to be so effective. Massive television coverage of a Patriot the appeared to have intercepted the second round of Scuds aimed at Dhahran gave the world the impression that the US already had effective missile defenses, which led Israel to ask for the immediate deployment of Patriots. The US responded by rushing 32 missiles to Israel in 17 hours.

Table 11.2

Iraqi Surface-To-Surface Missile Launches During The Gulf War

Result	Target			Total
	Israel	Saudi Arabia	Bahrain	
Total fired 40	48	3	91	
Missed country	1	3	2	6
Missed target area	15	11	1	27
Intercepted by Patriot	34	11	0	45
Hit target	0	13	0	13
Debris hit	7	7	0	14

Source: OSD Public Affairs, March, 1991

The Iraqi Scud strikes caused relatively limited direct damage. Detailed statistics on the effects of the Scud strikes on Saudi Arabia are not available, but it is clear that their effect was largely psychological. The threat of Scud strikes cleared the streets of Riyadh, and the fear of chemical attacks had a major impact on morale and led forced military units to dominate chemical gear and take shelter.[69] The one serious effect on Iraq's Scud strikes on Saudi Arabia was an accidental hit on a US barracks near Dhahran on February 25, which produced the only major Coalition losses to any Iraqi long range strike system.[70]

There are many different estimates of the damage from the Scud attacks on Israel, but Table 11.3 indicates that direct Scud damage killed a maximum of two people in Israel. Only 10 of the 232 people directly hurt by Scuds in Israel suffered more than superficial injuries, and only one was severely hurt, which indicates that the main damage was done by fear, shock, and misuse of civil defense equipment. In contrast, each V-1 falling on London directly killed 2.2 persons, and seriously injured 6.3, and each V-2 falling on London, killed 4.8 persons and seriously injured 11.7.[71] The physical impact of Iraq's Scud strikes was also limited. While some Israeli newspapers have talked about damage to 2,797 apartments before the deployment of the Patriot, and 9,029 after deployment of the Patriot, this damage generally consisted of broken windows. Only 74 apartments suffered significant damage, 40 before the deployment of Patriot and 34 afterwards.[72]

At the same time, the survivability of Iraq's missile launchers allowed it to achieve its only real military "success" of the war. This success was political and psychological, rather than physical and military, but it was still very real. The continuing Scud attacks gave Saddam Hussein immense prestige in some parts of the Arab world, and helped offset the impression of total defeat that surrounded most aspects of Iraq's performance during the war. The Scuds disrupted some aspects of the Coalition offensive air plan, and created the only real risk that the Coalition might be divided by Israel's entrance into the war.[73]

While the West has tended to focus on how many Scuds were or were not killed during the war, it is doubtful that most potential users of the Scud see such debates in the same way. It is likely that many radical states will see Iraq's experience as a lesson of the war, and will seek to acquire missiles and develop dispersal, decoy, and sheltering programs similar to -- or superior to -- Iraq's. They are likely to see long range missiles as systems that get immense political attention, even when they were not used, which gave Iraq a symbol of international power, and which could overcome many of the West's advantages in air defense and offensive capabilities. Like Iraq, they are likely to measure the value of such systems in terms of how they influence regional and Western perceptions, rather than simply in terms of war fighting effects..

Table 11.3

Iraqi Surface-To-Surface Missile Launches During The Gulf War

Direct Casualties Due to Missile Impact		Indirect Casualties	
Dead	2	Dead due to Heart Attack	4
Injured	232	Dead due to suffocation from misuse of gas mask	7
Total	234	Total dead	11
		Accidents from running or driving to cover	40
		Injuries from misuse of Atropine antidote	230
		Hospitalization for Acute anxiety	544
		Total injured	814
		Total dead and injured	825

Source: Adapted from Eliot Cohen, ed. The Gulf War Air Power Survey, Volume IV, Part I, pp. 33-332

Iraq's Missile Activity After The Gulf War

Events since the war have clarified some aspects of Iraq's pre-war missile capability. In its initial report to the UN after the war, Iraq declared that it had 52 ballistic missiles, 38 launchers, 30 Chemical-filled warheads, and 23 conventionally armed warheads at five sites. It then admitted that it had nine more missiles at one of its sites.[74] In the months that followed, however, the UN identified at least 17 facilities where the Iraqi government had conducted research, production, testing and repair of ballistic missiles, launchers, and rocket fuel.[75] By February 1992, the UN had destroyed all the stocks that Iraq had declared, and a substantial amount of additional equipment. By this time, the total included over 80 missiles, 11 missile decoys, dozens of fixed and mobile launchers, 8 missile transporters, and 146 missile storage units.[76]

As has been mentioned earlier, the UN also found that Iraq could have launched missiles with chemical warheads. The UN found the 30 Chemical warheads for Iraq's Scud missiles stored in the Dujael area, some 18 miles away from the position Iraq had declared. Sixteen used a unitary nerve gas warhead, and 14 used a binary warhead. They were, however, relatively crude manufactured warheads with limited carrying capacity. According to some experts, they had inadequate welds, and might have tumbled or disintegrated in flight. The warheads also lacked the technology to effectively and reliably disseminate chemical agents. It is likely, however, that at least some would have penetrated to the target, and released enough agent to at least be useful as a terror weapon.[77]

In spite of the UN effort, Iraq may still be concealing some missiles and launchers, as well as some of the manufacturing equipment, parts, and test equipment that it purchased before the war. Estimates based on data found by the UN Special Commission indicate that Iraq had imported a total of 819 Scuds from the former Soviet Union alone before the war, and that it might still have 100-200 missiles, and 12-20 launchers. In a testimony before Congress in January, 1992, the Director of the US Central Intelligence Agency estimated that Iraq might still possess "hundreds" of missiles. UN inspection teams in Iraq issued a somewhat similar estimate in November, 1992.[78]

Iraq could have deployed missiles in underground missile storage sites that it built before the war, and may have built new sites after the cease-fire.[79] Further, Iraq has continued to defy UN orders to destroy the equipment that the UN discovered. In February, 1993, Iraq deployed the special fuel trucks that were used to launch Scud missiles in areas outside Baghdad. in June and July, it attempted to deny UN inspectors access to its missile test ranges.[80]

As a result, it seems likely that Iraq will recover some Scud launching capabilities relatively soon after it ceases to be subject to UN inspection. Iraq may also be able to give such weapons better chemical warheads than it had at the time of the Gulf War. It could probably build such warheads covertly and use chemical weapons made in laboratory or non-military facilities. What is more uncertain is whether Iraq can obtain the liquid fuel and oxidizer necessary to launch any covert holdings of Scud missiles without building a new facility. According to one expert, it obtained all of its fuel and oxidizer supplies from the former Soviet Union before the Gulf War, and such supplies only have a storage life of 12-18 months.[81]

Iraq's Scud missiles would be vulnerable to point defense by the improved Patriot, and the US might be able to counter large scale attacks by attacking the launch sites with US air power. The US has no current way, however, to prevent Iraq from confronting the UN or some future coalition with some of the same "Scud hunt" problems that it had during the Gulf War: It would be almost impossible for the US to hunt out and destroy enough of Iraq's missile capabilities to halt all attacks.

It seems like that Iraq will also violate any agreements it makes about developing new long range missiles, and will attempt to acquire more lethal chemical and biological warheads for its ballistic missiles, and to develop and produce cruise missiles. Iraq will probably conclude that its Scud variants have probably lost much of their "terror" effect as long as they are only equipped with conventional warheads. Iraq may conclude that even chemical warheads will have limited value. While nerve gas warheads might kill several hundred people with a lucky strike, and affect some critical targets, Iraq will not be able to launch large enough volleys to achieve critical war fighting damage until it can get a major source of resupply for its present holdings of missiles and missile parts.

As for cruise missiles, these offer an important way of producing new systems and avoiding UN constraints. While Iraq may find major problems in acquiring long-range ballistic missiles, parts and manufacturing capability, it might be able to acquire what it needs to make cruise missiles covertly or on the black market even while UN sanctions are still in force.

Iraq has much of the technology needed to produce such weapons. It was working on modifications of the Chinese Silkworm (HY-2) cruise missile that was designed to have ranges of 75, 150, and 200 kilometers at its Nasr missile factory before the war.[82] Its use of remotely piloted vehicles during the Gulf War led to some initial fears that these might be equipped with chemical or biological agents. While Iraq has no more capability than Iran to develop and deploy a Tomahawk (TLAM)-like missile, it may be able to build a missile about half the size of a small fighter aircraft, and with a payload of about 500 kilograms. Iraq already has the technology needed for fusing and equipping such a system with CBW and cluster warheads. Navigation systems and jet engines would be a major potential problem.

Iraq should be able to solve the problem of acquiring a suitable guidance system over time. Current inertial navigation systems (INS) would introduce errors of at least several kilometers at ranges of 1,000 kilometers, and the risk of total guidance failure could exceed two-thirds of the missiles fired. However, Iraq may well be able to acquire better guidance systems using covert means. As has been discussed earlier, US studies indicate that a commercial differential global positioning system (GPS), integrated with the inertial navigation system (INS) and a radar altimeter, might produce an accuracy as good as 15 meters.[83] Some existing remotely piloted vehicles, such as the South African Skua claim such performance. Commercial technology is becoming available for differential global positioning system (GPS) guidance with accuracies of 2 to 5 meters.

Iraq would face problems in acquiring suitable engines. While there are many suitable commercially available reciprocating and gas turbine engines, finding a reliable and efficient turbofan engine for such an application might be difficult. It is doubtful that Iraq could design and build such an engine, although it has most of the needed design and manufacturing skills. Airframe-engine-warhead integration and testing would be challenging and possibly beyond Iraq's manufacturing skills. However, it is inherently easier to integrate and test a cruise missile than a long-range ballistic missile, and less detectable when such a system used coded or no telemetry.[84]

Such cruise missiles could reach a wide range of targets. A border area deployed system with only a 500-kilometer range could cover half of Iran, south eastern Turkey, all of Kuwait, the Gulf coast of Saudi Arabia, Bahrain and most of Qatar, the northern UAE, and northern Oman. A system with a 1,200 kilometer range could reach Israel, the eastern two-thirds of Turkey, most of Saudi Arabia and all of the other Southern Gulf states including Oman. Such a system could also be programmed to avoid major air defense concentrations at a sacrifice of about 20% of its range.

The Scud Hunt

The US recognized before Desert Storm began that Iraq might use its Scuds in an effort to bring Israel into the war -- although Secretary Cheney seems to have had a far better understanding of the strategic risks involved than USCENTCOM. USCENTCOM initially rejected the mission as having low priority, although its first estimates indicated that even if USCENTCOM was forced to strike the mobile Scud launchers, this would only require one squadron of F-15Es -- a conclusion that is surprising given the results of exercises and tests of the Scud hunting mission that were conducted in the US before Desert Storm.[85]

Memoirs written since the war provide contradictory pictures of how close Israel came to entering the war as a result of the Iraqi Scud strikes. General Schwarzkopf talks about Israel preparing to launch up to 100 sorties on January 18, but interviews in Israel indicate that the IAF did not favor such strikes. It is clear, however, that the fear of Israeli intervention in the war, and the need to reassure the Southern Gulf states, led the Coalition to suddenly improvise a massive Scud hunt. This improvisation led to several of the Coalition's losses of combat aircraft, and meant that Scud strikes had to take place at the expense of other missions -- including strikes against Iraqi ground forces. [86]

The Coalition flew a total of 1,460 strikes against Iraqi ballistic missile forces and capabilities. If one counts another 1,000 sorties that were flown to collect Scud targeting data -- and in "Scud patrols" where the attack aircraft normally diverted to another target if it did not find a likely Scud target -- the Coalition diverted roughly 2,500 sorties of its best and most capable strike aircraft to chasing Scuds.[87] This compares with a total of 2,990 wartime strikes on airfields, 1,370 on surface-to-air missiles, 1,170 on lines of communication, and 970 on nuclear-biological-chemical facilities.[88] At one point, the Coalition even considered shifting nearly all of its available strike/attack aircraft -- nearly 2,000 planes -- to a three day campaign against Scud launch sites in launch areas around Al

Qaim, Rutba, and other Iraqi cities. Britain sent in its SAS units and, on January 30, the US rushed in its Delta force and other specific force elements.[89]

The Coalition tried to create two "Scud boxes" to cover the most likely launch areas in Iraq for strikes against Israel and Saudi Arabia. Both the US and UK deployed special operations forces to help find the missiles. The US used DSP satellites to try to locate missile launches. It used F-15Es with LANTIRN to target and kill missiles at night, and F-16C/Ds and A-10s to cover roads and key launch areas during the day. It used B-52s and F-117As to hit possible storage and production facilities.

Air strikes were flown against mobile missile launchers, fixed-launch sites, and places where mobile launchers might hide (culverts, overpasses, etc.), production facilities, and support facilities. It is important to note, however, that most Scud strikes were little more than guess work, or were flown against targets that had little prospect of affecting the total number of Scud launches during the war. About 50% of the 1,460 sorties struck at possible hiding places like fixed structures, culverts, and underpasses. Most of these strikes could do little more than guess that a launcher might be present. Another 30% of the strikes were flown against production facilities and infrastructure. Only 15% (215) were flown against targets believed to be actual mobile launchers.[90]

All of these efforts did little more than hit decoys and fuel trucks -- although they may have reduced the Iraqi launch rate and Scud operating area.[91] The USAF Gulf War Air Power Survey concluded,[92]

> "Although Iraq's average weekly launch rate of modified Scuds during Desert Storm (14.7 launches/week) was about 35% lower that it had been in the absence of concerted attack during the 1988 'War of the Cities.' While launch rates -- particularly of coordinated salvos -- generally declined over the course of the Gulf War, it remains impossible to confirm the actual destruction of any Iraqi mobile launchers by Coalition aircraft. During the war, air crews reported destroying about eighty mobile launchers, and at least another 9-11 were claimed by US Special Operations Forces. Most of these reports undoubtedly stemmed from attacks that did destroy things found in the Scud launch areas. But, most of the objects involved -- though not all -- now appear to have been (1 decoys, (2) vehicles such as tanker trucks that were impossible to distinguish on infrared or radar sensors from mobile launchers and their associate support vehicles, or (3) objects that were unfortunate enough to have Scud-like signatures."

Why The Scuds Survived

Intelligence located many Scud production and support facilities, and most fixed missile sites, but it could not locate "mobile launch or intermediate assembly or preparation sites."[93] "Key portions of the target set -- notably the presurveyed launch sites and hiding places used by the mobile launchers -- were not identified prior to 17 January 1991, and, even in the face of intense efforts to find them and destroy them, the mobile launchers, their hiding places, and launch sites all proved to be remarkably elusive."[94]

A number of factors helped the Scuds survive:[95]

- o Intelligence largely failed to detect Iraq's dispersion of Scud missiles, and mobile launchers and support equipment during the period from the end of August to the end of Desert Shield.[96]
- o Intelligence and Coalition targeteers assumed that Iraq would rely on Soviet and Warsaw Pact launch practices which involved set-up, launch, tear down, and withdrawal times of 40-90 minutes. In practice, the Iraqis deployed rapidly to pre-surveyed sites, set up within a few minutes, ignored many of the normal calibrations required to attack small military targets, fired large urban area targets, launched, and rapidly left -- all within intervals as short as 10 minutes.[97] (It is important to note that improvements in commercial GPS receivers and civilian weather satellites will make it easier to set up and fire with more accuracy in the future.)
- o Iraq practiced excellent radio and radar emission control to avoid giving set up and launch signatures that patrolling aircraft could find. In spite of some wartime claims, it is unclear that the US COMINT and ELINT efforts using TLQ-17 "Sandcrabs", TENCAP, and other detection systems ever reliably detected Scud launches.[98]
- o The DSP satellite system was designed primarily for warning purposes or nuclear counterforce strikes and to target fixed missile forces, not for hunting mobile missile launchers with conventional weapons. DSP satellites covered the area every 12 seconds, and could detect the heat from the launch plume of the Scud -- although the Scuds only had about one-third of the heat signature of typical Soviet ICBMs. The use of two satellites also allowed the US to create a three dimensional model to estimate the trajectory and probable impact of each launch. The US could do this within about two minutes after launch and then transmit the data to the Gulf and Israel within the next three minutes. However, the launch location data that the DSP system provided was not precise enough to allow aircraft find the target, only provided about 90 seconds of early warning, and took about seven to nine minutes to communicate to air units. Advances like stereo imagery and real-time transmission of processing are being considered, to try to correct this situation.[99]

- o Tests showed that F-15E crews could not distinguish a Scud launcher during daytime unless its precise location was known before take-off, even if the launcher was in an area as small as a square mile. Out of the 42 Scud launches observed from the air during Desert Storm, only eight led to an aircraft finding something close enough to a launcher to attempt and attack.[100]
- o FLIR data did not prove accurate enough to acquire Scud targets at night.[101]
- o Iraq deployed decoys in their launch areas. There is a debate over how many decoys Iraq deployed and how many were hit by Coalition forces. Some experts feel that there were only a limited number of decoys and several were hit. Some feel that there were more decoys, most were not hit, and that Iraq deliberately increased traffic from other vehicles in the launch area to combine decoys with deception operations. It is clear that some Iraqi decoys were so realistic that UNSCOM inspectors could not distinguish them from real launchers on the ground at ranges of more than 25 meters.
- o Efforts to attack the related Iraqi C^4I/BM system had little impact. All that the launch units had to do was fire into the same general target areas, and little was needed by way of communications or added targeting information. The Iraqis used land lines and couriers to exercise command and control (which led them to operate near roads in spite of the Scud Hunt. While emissions were sometimes detected from their meteorological radars, these were infrequent, could never be correlated with Scud launchers, and Iraq conducted some 80% of its launches at night.[102]

Although various Coalition forces eventually made claims that total kills of 300% of the probable total Iraqi force, there is no evidence any of these forces had a single success.[103] They may have reduced Iraq's launch rate, but this is uncertain. Iraq did cut its launch rate after January 26, and limited launches to its northern launch area.[104] Figure 11.1 shows that thirty-three of Iraq's 88 launches occurred during the first week of Desert Storm. As a result, Iraq averaged 4.7 launches per day during the first week of the war. In contrast, Iraq only averaged 1.5 launches per day during the rest of the conflict.[105]

However, this may not reflect a highly effective Coalition suppression effort. Iraq knew that it could not achieve meaningful military results by maintaining high launch rates, and was launching, instead, to achieve political effect. Iraq had an incentive to conserve missiles for a war of unknown length until the ground campaign demonstrated that its strategy of attrition would be a decisive failure. The seeming success of the Patriot, and Israel's willingness not to join the conflict may also be credible explanations of any drop in Iraq's launch rate.

Further, the Gulf War Air Power Survey concluded that Iraq only needed a maximum of 10 mobile launchers to achieve its highest launch rate, and 19 launchers are known to have survived the war intact. This helps to explain why Iraq could suddenly increase its number of launches when the land offensive seemed likely, and then launched as many missiles in the last eight days of the war as it did during the first seven.[106] It was one of this new round of launches during February 21-26 that killed 28 and wounded 97 at the barracks in Dhahran.

Other arguments for the effectiveness of the Scud hunt in suppressing the Iraqi launch effort seem equally uncertain. Some experts have argued that air power was effective because Iraqi launch rates were lower in the Gulf War than in the Iran-Iraq War. However, it does not seem valid to compare Iraqi launch rates in 1988 to those in 1991 because a different missile was being used for different political and strategic purposes. It also is of uncertain value to talk about changes in the "volley rate" or "salvo rate." It is true that the first 42 Scuds were fired in salvos, while 27 of the last 39 Scud firings were launched separately.[107] There is no clear reason why Iraq needed to fire its Scuds in volleys or salvos once it began to fire solely for political effect, however, and the data are somewhat suspect since DIA arbitrarily defined this rate as the maximum number of missiles launched in three minutes. No evidence has surfaced that firing volleys using this precise definition was ever an Iraqi goal.

What does seem likely is that the Coalition air attacks inhibited the resupply of Scud missiles to Iraqi mobile launchers, forced some launchers to move closer to missile supply depots, and restricted firing from some launch areas. However, the precise data supporting this argument are classified and cannot be addressed in detail.[108]

Figure 11.1

Iraqi Scud Launch Rates During Desert Storm

Daily Launch Rates

By Week Launch Totals and Maximum Salvo Size

Sources: Eliot Cohen, ed., Gulf War Air Power Survey, Volume II, Part II, pp. 337 and 339.

Lessons from the Scud Hunt

The need to find better ways to locate and kill dispersed mobile missile launchers is a clear lesson of the Gulf War, and is a lesson that the US has already given high priority. A number of classified technologies have been proposed to help improve targeting. New attack methods have also been proposed, including attack missiles with air-to-surface missiles in the boost phase. Such efforts are well worth exploring, but it is important to note that the fact that Iraq did not use its weapons as US intelligence predicted makes it extremely important to address scenarios different from the one Iraq followed in the Gulf War.

- o If Iraq had used its fixed launchers to launch on warning or under attack, a substantial number of its missiles -- if not all -- would have successfully launched.
- o The Scud was a large and highly visible weapon, and more modern ballistic and cruise missiles may be much harder to detect.
- o It is cheap to add more accurate decoys, and TELs are relatively cheap in comparison with the total cost of a missile and warhead with a weapon of mass destruction. Iraq was deploying its own-Iraqi made mobile launchers before the Gulf War, and a force with a ratio of one TEL per missile would be more difficult to attack, have more volley capability, and present a more serious threat in terms of intimidation and threats of retaliation.
- o Iraq would have faced far fewer constraints if it had more modern missile technology that allowed TEL to conduct independent launch operations from any point in Iraq, and had not faced some constraints in its launch areas.
- o The Scud hunt was highly dependent on Iraq's restraint or inability to use missiles armed with weapons of mass destruction. The time urgency of strikes on missiles would be very different, and the need to destroy the missile -- rather than the launcher --would be much greater.
- o Iraq could have dispersed single TELs over a wide national area and then armed them with weapons of mass destruction. This would have given Iraq a substantial launch under attack option, and would present search and kill problems far more difficult than those that the Coalition dealt with during the Gulf War.
- o Iraq did not put missile launchers in populated areas, but put other weapons in such areas. As has been discussed earlier, Coalition or US rules of engagement that over-emphasize the protection of civilian life and cutting collateral damage could present serious problems if high value targets like Scuds were hidden in populated areas.
- o Iraq did not mix missile strikes and long range air strikes. In the future, Third World states may be able to disperse combinations of strike aircraft, ballistic missiles, and

cruise missiles armed with weapons of mass destruction creating an extremely complicated problem in countering three different weapons systems at once -- all of which can inflict major damage.

o Future threats may mix any missile forces with unconventional delivery systems like the use of civilian aircraft and ships, and smuggled devices.

These factors must be kept carefully in mind in dealing with the counter proliferation problem. The last lesson to be drawn from Iraq's performance during the Gulf War is that proliferators are predictable, and other states will be able to take a very different approach to using missiles and other delivery systems in the future. Counter-proliferation efforts based on refighting the Gulf War and solving the Scud hunt problem are likely to prove wasteful and stupid. Counter-proliferation and counter-missile strikes must deal with the world that is coming into being, and not with the world that was.

The Patriot and the Anti-Missile War.

The debate over the effectiveness of the Patriot in destroying Scud warheads has been one of the most bitter and confusing debates about the lessons of the Gulf War. Much of this debate, however, stems from misperceptions on both side. the advocates of Patriot rush to praise the system on the basis of crew claims and TV coverage during the war. The Army rushed to judgment on the basis of operator reports, and claimed that the Patriot had intercepted most of the Iraqi Scuds that hit Israel and Saudi Arabia. These statements led President Bush to say that the Patriot was, "proof positive that missile defense systems work."[109] Even in March, 1991 -- after better data were available -- the Army issued press releases claiming that, "Of the 47 Scuds against which it was fired, Patriot successfully intercepted 45...throughout its entire period of employment in SWA, the system demonstrated an overall operational readiness rate above 95%."[110]

During the months that followed, outside critics charged that the Patriot was almost totally ineffective. They issued studies indicating that the Patriot had hit no Scud warheads. Some charged that the Patriots might actually have added to the damage the Scuds inflicted Israel by adding to the missile debris that fell in or near Tel Aviv.

This mix of exaggerated praise and criticism has triggered a debate that has taken on much of the character of the earlier debate over SDI -- with each side making extreme claims and treating the issue in ideological, if not quasi-religious, terms. The data now available indicate, however, that the truth lies somewhere between the Army position and that of its critics, although they also indicate that there is no way to establish all of the facts involved.

The Technical Capabilities of the Patriot Systems Deployed in the Gulf War

In order to understand the issues involved, it is necessary to understand some of the capabilities of the Patriot system. The MIM-104 Patriot fire unit, or battery, consists of an AN/MQS-104 engagement control station (ECS) with the computer that controls the sequence of engagement, monitors all systems for faults, and controls communication between batteries. There is a single AN/MPQ-53 phased array G-band radar that replaces five separate radars in the Nike-Hercules, and which is electronically steered. The radar can track up to 50 aircraft and 5 missiles at the same time. An AN/TPX-46 interrogator acts as the identification of friend or foe (IFF) system using supplementary antenna arrays on the main radar. The unit has five to eight M901 launchers, each of which has four missiles, mounted on M977 trucks. Each launcher has its own power generators and its own communications link with the ECS. A Patriot unit also has two 150 kilowatt generators mounted on a separate truck.[111]

The ECS control van has two radar screens that display incoming missile tracks. The engagement station has two operators that use a track ball to place a cursor on the target track, and can then get track evaluation data on the track -- including threat level, speed, range, altitude, and incoming vector. Once a decision to engage is made, engagement is normally automatic with a manual override. A communications chief controls the UHF link to higher command levels and assists the operators in an engagement. Central control is provided at the battalion level, but many fire decisions are made at the battery level, and during the Gulf war batteries often had to consult to determine which unit would engage.[112]

A Patriot battalion controls six fire units or batteries, and has a total of 30-48 launchers, and 300-400 missiles including reloads. The missile is a large solid-fueled missile that weighs about 2,200 pounds, and is 17.4 feet long and 16.1 inches in diameter. The mature missile costs about $680,000 per missile. The nominal range of Patriot is 60 kilometers, and it can fire at altitudes from 400 to 72,000 feet. It leaves the launcher at speeds close to Mach 6 and can maneuver and intercept at Mach 3.[113] The system can detect aircraft at ranges up to 75 miles and intercept effectively at ranges of 50 miles.[114]

The Patriot uses a track via missile (TVM) system. Its main radar detects, tracks, and illuminates the target, and tracks the Patriot interceptor missile once it is launched. At about mid-course, the monopulse seeker array in the interceptor is turned on. The ECS directs it to look in the direction of the target, and the passive seeker in the interceptor then homes in on the illuminated target. The interceptor uses a continuous communications link back to the ECS which uses the data from the interceptor to compare the target locations produced by the main radar and the seeker in the Patriot interceptor. The ECS then continuously gives the interceptor the resolution that will bring it to its target. This TVM approach provides higher capacity, anti-jamming capability, and accuracy at long ranges. It reduces the work burden and tracking problems of the main radar, and eliminates the need for an expensive semi-active seeker and processor, and high radiated power that might lead to detection, jamming, or the use of anti-radiation missiles. The TVM sequence can be used to provide full automatic control, but there is also a computer interface which allows the operators to override any function.[115]

The Patriot system has evolved steadily since its conception. Its origins can be traced back to a surface-to-air missile system project started in 1967 called the SAM-D. The name of the project was changed from SAM-D to the Patriot in 1976. The first Patriots entered low rate production in September, 1982, and the first units were deployed to Europe in 1985. The Patriot went through a long period of teething problems that led to many software and hardware changes during this process.

The PAC-1 improvement program for the Patriot was the result of a decision to provide software to give the Patriot limited anti-tactical ballistic missile (ATBM) intercept capability designed around the kind of short range tactical missile still permitted under the INF Treaty. This decision was triggered by the recommendations in a Defense Science Board report issued in the late 1970s, and by a US Army effort to create a suitable development program that began in 1978. The Army development program was approved in late 1980, and completed in December 1988.

Deployment of the PAC-1 upgrade throughout the Patriot force was completed in 1989. The resulting software changes involved modifications in the engagement control station and radar to provide the ability to detect and track typical short range surface-to-surface missile trajectories, but they were not intended to provide area defense against a Scud-level threat or wide area coverage. They were designed to cover a three-mile radius with a high probability of success, and the PAC-1 successfully intercepted 17 missiles in 17 trials of this kind during 1986 to January, 1991.[116]

The Patriot received further improvements just before the Gulf War in the form of a PAC-2 program. While the PAC-1 program was largely a software program, the PAC-2 improvements involved both further software changes and hardware improvements to give the missile a new fuse, and heavier warhead fragments. The PAC-2 improvements were critical to the Patriot's ATBM capability, because they broadened its radius of defense coverage to about 12 miles, and provided the higher fuse speed, dual beam proximity fuse capability, and warhead design needed for more effective missile killing. With the upgrades, the Patriot system could detect incoming Iraqi Scud missiles at ranges of 35-50 miles, although it normally intercepted at ranges of 15 miles or less.[117]

The PAC-2, however was scarcely a mature system when the Gulf War began. While the Patriot was a highly capable air defense system by the time it was sent to the Gulf -- probably the most advanced heavy surface-to-air missile system in the world -- its anti-tactical ballistic missile capabilities were still only moderate. Only three PAC-2 missiles were actually completed when Iraq invaded Kuwait, and it is a tribute to the manufacturers concerned that the US Army was able to deploy 480 PAC-2s by the time Desert Storm began.[118]

Patriot Deployments in the Gulf War

As might be expected from a system being rushed into a new role with a new missile, the deployment of the Patriot to Saudi Arabia exposed problems in bringing the Patriot to full readiness. There were recurrent problems with air filters because the system was not designed for the fine dust in the Gulf area.[119] It took months of organizational effort, testing, and modification to bring the units to full readiness in their air defense, and ATBM mode. As initially deployed, the Patriot units would have had very limited effectiveness in the ATBM mode.

The five and one-half months provided by Desert Shield allowed the US to correct many of these problems, build more PAC-2 missiles, and bring in additional missile units. Nevertheless, the problems in the PAC-2 scarcely ended with Desert Shield. Radars still were not always reliable, and US Patriot crews in Saudi Arabia stated during the war that, "The system is so picky --one little problem and it will shut down."[120] The PAC-2 went through at least two sets of software changes during Desert Shield and Desert Storm, and had to be extensively reprogrammed to correct a range gate error.[121]

Israel, in contrast, rejected a US offer to deploy the Patriot before Desert Storm, and only decided to accept US-manned missiles once it came under attack. The units deployed to Israel were rushed in with only a few days warning and only began to deploy on January 19. Some units had US crews trained for Europe and others had Israeli crews that had largely completed their training. Neither set of crews seemed to have been fully briefed on the teething problems of the Patriot deployment to Saudi Arabia. The Israeli government was suddenly forced to make decisions about the deployment and rules of engagement for the Patriots sent to Israel that may have compounded the problem of using a missile designed for joint or limited area defense in an area defense mode.[122]

The Patriot units sent to Saudi Arabia had both the PAC-1 and PAC-2 versions of the missile. Once the war began, the Patriot's phased array radar was routinely able to detect Scud missiles at ranges of more than 100 miles. This provided about 6-7 minutes of warning, and this warning was normally enhanced by launch detection data from the US DSP satellite system.[123] The Patriot engaged the Scud at ranges of 20-30 miles. The initial phase of the intercept normally began at altitudes of 100,000 feet, and actual intercepts normally occurred at ranges of 6 to 18 miles, although intercepts in Israel were attempted closer to the launcher, and at relatively low altitudes for such a system. The time from engagement to moment of attempted intercept was only 15-18 seconds, and required automatic or semi-automatic launch of the missile. Patriot interceptors were normally fired in volleys of two, from different launch units to increase the probability of kill.

The details surrounding some aspects of the Patriot's behavior during the Gulf War remain classified, and data are lacking on other aspects. Some points, however, are clear. The Patriot had technical problems in intercepting Scud warheads. The regular Scud is a high apogee missile that closes at speeds approaching 1,600-1,800 meters per second. The PAC 2's design parameters are classified, but the missiles were clearly optimized around intercepting regular Scuds, and timing delays of even 1 1/1000th of a second are enough to make an intercept fail even with ordinary Scuds. Iraq's extended range Scuds flew longer, and closed at a significantly higher speed of 2,000-2,200 meters per second. (Some ICBMs can reach 6,000-8,000 meters per second.)[124]

As has been noted earlier, the fuel sections that Iraq added to its modified Scuds were poorly welded, and the missiles were less stable in both the ascent and reentry phase than the regular Scuds. The Iraqi missiles often broke up as they reentered, producing violent twisting or "corkscrew" motions, and complex radar cross sections, that the Patriot was not initially designed or programmed to deal with.

This Scud warhead break up problem was not recognized before Iraq began its Scud launches. The Patriot crews initially attempted to deal with these problems by firing at every major fragment of each missile. They fired three to six PAC-2 missiles per incoming Scud -- an expensive procedure that threatened to deplete the limited stocks of PAC-2 missiles. When the cause of this problem became apparent, the Patriot crews in Saudi Arabia and Israel took somewhat different approaches to trying to take advantage of the capability of the Patriot's radar to recognize the warhead because it flew more quickly and with a straighter and more predictable trajectory.

The US Army states that its missile units in Saudi Arabia had experienced crews that had deployed the units long before they were sent to the Gulf. It indicates that once it became apparent that the Scuds were breaking up, these crews attempted to dealt with the break-up problem by using features of the Patriot that automatically fired at the lead and highest velocity target, and reduced the risk of wasting missiles on the Scud body. Other reporting indicates, however, that at least a few US crews took the system down for 1-2 seconds to prevent lock on debris, and actually fired about 20-30% of their missiles in the semi-automatic mode.[125]

The two Israeli Defense Force units operating the Patriot attempted to deal the problem by placing the system in a mode where the commander had to manually decide to engage the object while the system tracked semi-automatically. The Israelis feel this method helped target and destroy the warhead. In contrast, some US Army experts feel that the Israeli method engagement degraded the system's performance.[126]

There is a debate about the extent to which Patriot missiles caused collateral damage, and one report indicates that the self-destruct mechanism on four of the missiles fired in Israel and then landed in the Tel Aviv area.[127] There is also a debate over crew proficiency. US Army experts feel that inexperienced Israeli crews sometimes overrode the unit's fire control computer under conditions where successful engagement was doubtful, and where the risk of a missile hitting a populated area was high. Some Israeli's deny this, and claim that their intercept rate went up after they shifted away from reliance on purely automatic fire. These debates are hard to put in context. The focus on the nationality of the crews has led to indifference as to the details of human factors in terms of crew experience and differences in proficiency. Some post-war studies also ignore the fact that the Scuds that fired against Israel also flew longer ranges, which seems to have complicated their break-up, and increased the terminal velocity of the warhead.[128]

The US Army now agrees that neither the US nor Israeli crews scored a high ratio of hits on Scud warheads using the procedures and PAC-2 software that were standard when Desert Storm began. It took at least two sets of software improvements to improve the kill capability against the Scud warhead, and it took time for Raytheon, the manufacturer of the Patriot, to find new software solutions.[129]

These software solutions addressed the need to intercept faster missiles, to focus on the radar signature that was most likely to be the warhead, and to eliminate a routine that fired two missiles in sequence so they would intercept at 12 kilometers and then at 6 kilometers to ensure that the warhead would be hit. This sequencing did not work when the missile broke-up and when the second interceptor had no way to target on the warhead. They also seem to have corrected timing errors that sometimes could lead the interceptor to intercept the rear of the Scud.

The US Army issued the tasking for the second effort to improve the PAC's software on January 26, but there were limits to how quickly such changes could be made. The project was rushed forward, but the resulting Version 35 software which was intended to improve the ability of the Patriot to discriminate the warhead from the missile body only arrived in theater on February 22/23 -- when the war was nearly over.[130]

Tragically, this Version 35 software seems to have played a role in the Scud strike that hit a US barracks on February 25. Although the new software improved kill capability against warheads, it meant that the Patriot accumulated a one micro-second timing error for every second of operation. The US units did not shut down the Patriots in Dhahran -- as was standard practice in Europe -- and kept some operating for more than four days. This eventually led to a one-third second accumulated timing error, which was enough to make the Patriot radar search an area 700 meters away from the real track. This surveillance range gate error was serious enough so the radar did not search the right area, and failed to detect the incoming missile.[131]

Trying to Measure Effectiveness

Like most US smart weapons, it is impossible to resolve many of the uncertainties surrounding the Patriot's effectiveness. The Army initially relied largely on human after-action reports in making its initial estimates that the Patriot was 90% effective -- a procedure it later admitted was a mistake.[132] Engagements occurred so quickly that no one could visually establish the facts from the ground, or with any of the relatively slow speed film and television equipment available.

The recording devices designed to keep a record of all firing data were not fully ready during the Gulf War, and data for other techniques like hard copy track amp data were only available for 20% of the cases where the Army recorded a warhead kill. Problems occurred in operator reports, and in the battalion level ICC data -- which were only available for one claimed kill. Data were not available for many Patriot launches even for the indicators the US Army could use to measure the Patriot's effectiveness The US Army could only find data for every category it used to judge a hit for one-third of the missile firings it claimed produced a kill.[133]

Patriot units could track the performance of each missile fired with digital telemetry data up to the point where the Patriot reached a target. These data were recorded for some units using digital recorders, but Patriot units were not equipped with equipment that could precisely verify damage effects or a warhead kill.[134]

Israel used recorders and computer recorders to track Scud fragments, and carried out an operations research effort to try to improve the missile's performance.[135] Some sources claim that the data they provided to the US helped Raytheon to modify the Patriot software to select out Scud warheads from parts of the body, although this is disputed.[136] Both Israeli and US sources state that some of the Israeli data were inconclusive or had internal discrepancies.[137]

It was possible to survey some of the ground for Scud and Patriot fragments and impact effects during and after the war, but the details of these efforts remain classified and the Army did not fully survey some of the ground where it claimed no collateral damage occurred. Tracking damage to the warhead from damage effects was also difficult in several respects. The Patriot system scoured a "kill" when the radar and ECS indicated that the missile intercepted at the desired point, regardless of whether it actually hit the missile.[138] Conclusive evidence of a kill required physical evidence that the Patriot had struck a warhead that failed to function. The absence of such evidence did not, however, mean the firing was a failure. Damage effects were difficult to assess because the explosive content of the longer range Scud variants used against Israel and Saudi Arabia was evidently under 400 kilograms, and the remaining fuel in the Scud booster and parts from the Scud could also produce damage. Some damage could be characterized, but much could not.[139]

In summary, there is no way to determine exactly how many interceptors tracked the Scud warhead, as distinguished from tracked missile debris or other targets. None of the unclassified reports, "pro" or "con," on the Patriot since the Gulf War provide these data, and none can be regarded as analytically valid. Accurate commentary would require access to the data base on each separate Patriot missile firing and on all the results in terms of digital data, claims regarding a warhead kill versus other effects, and analysis of the damage on the ground.[140]

A similar uncertainty affects the extent to which Patriots caused collateral damage. Patriots damaged some civilian facilities in Israel and Saudi Arabia. While the precise details cannot be separated from what is often impressionistic and exaggerated reporting, one building was hit in Riyadh, and several missiles fell near Al-Khobar and Dhahran. At least two missiles damaged buildings in the area around Tel Aviv, and several more struck in the greater Tel Aviv and Haifa areas.[141] The issue of whether or not some damage took place in Israel and Saudi Arabia from Patriot missiles -- or from Scud fragments that the Patriot hit -- can, however, miss a key point. Collateral damage from Patriot fragments and missile boosters cannot be ignored, but the real mission of the Patriot was to prevent a successful attack by a functioning warhead using a weapon of mass destruction. Minor levels of collateral damage are not the real test of the Patriot's success.

These problems in assessing the Patriot's performance are compounded by the fact that the Patriot was deployed and used in different ways in Saudi Arabia and Israel. In Saudi Arabia, it was deployed primarily to defend key military targets -- although launchers were spread out over unusually long distances to provide improved secondary defense coverage of Saudi cities. The Patriot was not deployed or used to defend population centers in a very wide area defense mode -- a mission for which it was not designed. The six Patriot batteries that were rushed into Israel (two Israeli operated and four US Army operated) were used to defend two urban complexes:

The Patriot's effectiveness in Israel is difficult to analyze for several reasons. Iraq fired 12 out of a total of 42 Scuds before the Patriots arrived. It took time to bring the

Patriot units deployed to Israel to full effectiveness, and Israel used its own methods of citing and rules of engagement. Interviews indicate that only about half of the Scuds fired against Israel after the deployment of the Patriot were used according to the recommended US Army rules of engagement. As has been touched upon earlier, the US Army feels that these Israeli decisions limited the effectiveness of the Patriot missile, while increasing the risk of collateral damage. The Israelis feel that their decision to try to manually control the Patriot to attack the Scud warheads before they received changes to the Patriot software increased its effectiveness.[142]

However, interviews indicate that the US Army had concluded by 1993 that the approximately 50 Patriots fired intercepted a relatively small number of the 42 missiles that Iraq fired at Israel. Army sources indicated that they had high confidence that the Patriot was effective against 40-50% of the roughly 15 Scuds it could engage. Israeli sources are notably more pessimistic, and talk about a "4% hit rate" or no kills at all.[143]

The US Army concluded that about 30 of the 46 Scud missiles fired at Saudi Arabia were engagable. In its revised reporting in 1992, the Army indicated that it fired about 100 Patriots against this missiles, that it scored a significant hit against 23-27 Scuds, and that it had a success rate of 70%. Interviews with Army experts in 1983, however, indicate that the Patriots were now estimated to be effective against only 17-20 of the Scuds engaged.[144]

Other sources are as vague or conflicting. The US General Accounting Office found that, "About 9% of the Patriot's Operation Desert Storm engagements are supported by the strongest evidence that an engagement resulted in a warhead kill...Lesser evidence exists for the other 16% of the engagements that the US Army classified as high confidence of a warhead kill."[145] An Israeli source claims that the were no confirmed warhead kills in Israel.[146]

One fact is clear: If the Iraqi Scuds had been armed with nuclear or high lethality biological warheads, they would still have done devastating damage. Further, none of the previous data provided a clear picture of the performance of Patriot at a normal peacetime readiness rate in the event of a surprise attack, or in the event of a volley attack deliberately designed to saturate or confuse the system.

At the same time, the Patriot was as much of a psychological and political success as the Scud. It helped shape the course of the war, and after the full account was taken of its developmental nature and design limitations, it showed an impressive ability to improve its kill rate over time. Israel, as well as Saudi Arabia, chose to keep the Patriot after the war, and General Uri Ram, who commanded Israel's air defense forces during the Persian Gulf War noted,[147]

> "Critics of the Patriot's operational success during the Gulf War have spent the past two years examining scattered (and in their own words unreliable and often conflicting) ground damage and injury reports, and dissecting videotape from television news cameras...Yet, without access to valid but classified and secret data, they have branded engagement success figures -- as assessed by the US Army and supported by Israeli defense force and Saudi Arabian military -- as a total distortion of what actually happened...The Patriot was a success, but it wasn't perfect...At the time of the war, the Patriot had not been designed to provide protection of sprawling population centers, nor to handle tactical ballistic missiles with the velocity of the Iraqi modified Scuds. Furthermore, anomalous characteristics of these Scuds, discovered only after the war started, made the ...job more difficult. ...There was nothing in the Patriot software to accomplish this task or to deal with the severe maneuvers of the very high Scud velocities...Luckily for us, the system was able to be reconfigured for use against Iraqi ballistic missiles in a very short period of time."

Uncertain Lessons from an Uncertain Experience

History has already made much of the argument over the lessons to be learned from the performance of the Patriot moot. The technology to improve the Patriot's ATBM capabilities was not fully field tested at the time of Desert Storm, and its design limitations eliminate any expectation of it providing anything approaching a leak-proof defense system. It also lacked the range to intercept at points where it could prevent missile debris and warheads falling on populated areas.

The PAC-2 has already had significant refinements. The Patriot Quick Response Program (ORP) was instituted in 1991-1992. This program was designed to quickly identify and field improvements to correct the shortcomings revealed by Desert Storm. It includes emplacement upgrades for paid, accurate fire unit emplacement, a capability to remote launchers up to 12 kilometers from the radar, and radar enhancements to improve theater ballistic missile detection and increase system survivability. This QRP configuration of Patriot is already deployed in Saudi Arabia and other countries. A companion program, the guidance enhancement missile (GEM) includes engineering improvements to the Patriot missile to improve lethality, especially against the Desert Storm class of threats, and the first GEM missiles will be fielded in 1995.[148]

The US Army is developing a PAC-3. According to various US Army and press reports, this missile may have up to a 50% increase in the missile radius of protection, greatly improved positive target identification, up to a 90% increase in missile intercept height, improved radars with twice the power, a high technology exciter, software designed to deal with the break up and warhead characterization problem, and a capability to intercept faster missiles.[149] There are two possible variants of the PAC-3. One is the Extended Range Interceptor (ERINT) missile which can attack both ballistic missiles and air breathing threats. It uses a kinetic energy (hit-to-kill) warhead, an active Ka-band seeker, aerodynamic control vanes, impulse altitude control thrusters, inertial flyout and uplink guidance, and has an approximate speed of Mach 5.[150] Sixteen of these missiles can be carried per launcher. The other is a heavier Multimode Missile (MMM) with a blast-fragmentation warhead, an Active/C-Band TVM seeker, command/uplink guidance, and a maximum speed of Mach 5.6. This missile weighs 2,000 pounds versus 713 pounds for the ERINT, and only four missiles can be fitted to a launcher.[151] According to various press reports, these growth versions of Patriot would provide a remote launch capability, use a launcher with up to an 80% faster reload time, and improve virtually every aspect of C^4 capability.

The US is also upgrading the theater missile defense capabilities of the IHawk, and is examining a wide range of mid to long-term alternatives to the Patriot, and radically improved sensor systems to detect and target missiles like the Scud.[152] One key option is the deployment of a Theater High Altitude Area Defense (THAAD) system to provide comprehensive integrated area defense. Other options include ship-based systems that could give the Aegis class of ships area defense capable against theater missile threats, and various types of boost-phase air-launched systems.[153] Israel is developing a program with area defense capability called Arrow, and Russia has talked about selling a version of its SA-10 with some ATBM capability. All of these systems would change the basis for judging the merits of an ATBM beyond any clear relation to the performance of Patriot during the Gulf War. At the same time, many potential threat countries are acquiring improved ballistic missiles and cruise missile capabilities.[154]

The most that can be said about the lessons of the Gulf War relating to ATBMs at this point is that they indicate that the value or non-value of these new systems will depend on their ultimate cost and whether they do or do not succeed in making major improvements in areas like the need for a heavier or more lethal warhead, longer range, faster acceleration, better long range warning and targeting, and software to adapt to area coverage. They also indicate that much will depend on the desired coverage and lethality provided by the overall system. It is one thing to deploy a system that can be expected to achieve reasonable lethality against a limited number of launches and protect a moderate area. It is another thing to deploy a system that can provide a near leak proof defense capability against a large "salvo" of missile armed with nuclear warheads or highly lethal biological weapons.

At the same time, the debate over the Patriot's performance in the Gulf War is a classic lesson in a totally different aspect of war. It teaches that rushing to judgment -- and acting as either the "cheerleader" or opponent of a weapon -- is not a way to learn the lessons of modern war. It teaches that analysts serve no one's interest by stretching their conclusions beyond the weight of the evidence. The value of an anti-ballistic missile system is not to be determined by the past, or by rhetoric or ideology -- pro or con. Rather, it is to be determined by the precise nature of the threat, the precise effectiveness of the missile, its cost, and the relative priority that a given nation has for the amount of money. The value or non-value of anti-missile defense should be determined by the facts surrounding future threats and defense capabilities, and not by politics.

Iraq's "Super Guns"

Although Iraq's efforts to develop cruise missiles had not made major progress by the time of the Gulf War, Iraq experimented with other long-range weapons delivery systems. It had begun to assemble " super guns," although these systems were still in the developmental stage when the Gulf War began.[155] This Iraqi effort was called "Project Babylon" and it became public knowledge on April 10, 1990, when British customs officials at Teeside seized eight steel tubes bound for Iraq. It later became clear that these tubes were part of a giant "cannon" that was intended to hurl rocket projectiles hundreds of miles. It also became clear that these tubes were part of a long series of shipments. Britain later disclosed that 44 such tubes had already been sent to Iraq, and that devices that could serve as the breach for such a "gun" had been intercepted in Turkey.[156]

These "super guns" were designed by Dr. Gerald Bull, a Canadian ballistics expert, and were an extension of earlier work that Bull had done for the US and Canada in what was called "Project Harp".[157] UN inspection teams also found after the war that Iraq was developing two weapons as part of this project: A 356mm gun and two 1000mm prototype guns.

Iraq had been testing an experimental version of the 356mm gun for several years. It had three versions of the 356mm gun: One was a 55.5 meter test gun and two were 30 meter long guns with three sections. These were designed to be mobile guns capable of elevating and traversing. The test gun had five barrel sections and was built into the slope of a mountain at Jabal Hamrayn, near Bir Ugla, about 200 kilometers north of Baghdad. This version of gun had been tested seven times with slugs for proof of principle at relatively short ranges, but evidently had not been used for about a year before the Gulf War.[158] According to some reports, the 356mm test gun had fired a projectile of 75 kilograms (165 pound), with a payload of 15 kilograms (30 pounds) of high explosives.

While some of its design data claimed a maximum range of 750 kilometers, its real-world range was probably about 150 kilometers (93 miles) to 180 kilometers (120 miles).[159]

Other data indicate that the 356mm mobile guns were intended to fire a 3.6 meter long rocket called the Babylon II Ground Launched Rocket (GLR). They were supposed to use a 325 kilogram charge to fire the rocket at a muzzle speed of 1,300 meters per second. The rocket was to be protected from blast damage by the gun by a base plate and a sleeve or casing fitted over its motors. The rocket's 225 kilograms of propellant were to ignite once it left the barrel, and increase the rocket's velocity to nine times the speed of sound. It had six fins that were supposed to deploy after it left the gun barrel, a guidance system, and a design payload of 22 kilograms.[160] The rocket was designed to reached a height of up to 310 kilometers and a range of up to 1,215 kilometers.[161] Israel was some 825 kilometers (550 miles) away from the Iraqi test site.[162]

These designs were technically impressive, but they raise some serious questions about the value of such a weapon. A 22 kilogram payload was too small to have much meaning as a means of delivering weapons of mass destruction or a means of launching a satellite. Iraq was also working on another 356mm rocket with a similar range and a 100 kilogram payload. Even a 100 kilogram payload, however, would still have been too small for even the simplest military satellite purposes -- even if it could have achieved a fractional orbit. It also would have been too small for useful chemical weapons delivery unless it could be fired with great accuracy in large numbers, and too small for the delivery of anything but the most efficient nuclear and biological weapons -- weapons far beyond Iraq's design capability at the time of the Gulf War.

Neither of the 1000mm guns were assembled, and only one had sufficient components to indicate that it might be operational in the near future. The parts for this gun were stored at Iskandariyah. According to some reports, it was supposed to be about 131 feet (40 meters) long, with a 39" breech, and weighs up to 402 tons.[163] Data released by the UN inspection teams indicated that each gun was to be in 26 sections and about 156 meters long (the length of 1 1/2 football fields). UN experts calculated that these guns were designed to fire a 1,000 kilogram (2,200 pound) projective with 408 kilograms (898 pounds) of high explosive or payload.[164] Some experts estimated that it would have been able to fire weapons of mass destruction at ranges of up to 1,000 miles; others estimated that it was designed to put payloads of 300 to 500 pounds into orbit.[165]

Bull seems to have been working on a rocket-assisted shell for the 1000 mm gun, but this design was in its early conceptual stages, and might have taken a decade to implement -- if it was practical at all. The design called for a rocket projectile that the gun could fire at three kilometers per second and which would be fired to a height of 27 kilometers. A first stage rocket was then supposed to take the projectile to 48 kilometers, and a second stage rocket was to accelerate it to a velocity of 80 kilometers, and a third stage rocket was then supposed to accelerate the projectile to 105 kilometers, and to a speed of nine kilometers per second. This sequence was supposed to take the projectile to a fractional orbit at an altitude of 1,700-2,000 kilometers, and a final insert motor was then supposed to put it fully into orbit. All of this was to be done using automatic timing, without radio control or correction from the ground.

It is far from clear that this combination of a 1000mm gun and rocket projectile would have served its purpose. The ultimate payload might still have been too small to launch a payload large enough to act as a militarily significant communication satellite or to serve useful intelligence needs, and it is far from clear that Bull could have solved the timing and acceleration problems without the resources of a nation with far more advanced technical capabilities than those of Iraq. Further, it is unclear that Bull had designed a breech system capable of handling the immense recoil from the larger gun.[166]

The situation is somewhat different in terms of the 1000mm gun's ability to fire weapons of mass destruction. There are indications that Iraq planned to target the guns against Israel and use shells with biological weapons, although it is unclear whether Iraq's plans had moved beyond the conceptual stage. The design of such a rocket-assisted shell would have been very complicated, and Bull does not seem to have worked on such a design. It is very doubtful that Iraq could have designed such a round, and such a design would challenge the design, manufacturing, test, and evaluation capabilities of even the most sophisticated country. [167]

In short, the "super guns" might ultimately have proved to be little more than the "super toys" of a brilliant designer. The 1000mm guns were at best rail mobile, and it is unclear that the 1000mm gun could have been moved without disassembly. Once they fired, their trajectory could be used to target them. This might not have presented problems in firing at Iran, because Iraq had superior fighter cover, but would have presented serious problems in any attack on Israel. It is also unclear that most of the required sensor, processing, and communications technologies could withstand the shock of firing the gun. Further, the guns presented major problems in terms of designing a reliable shell that can effectively disperse biological agents, and their rate of fire seems to be too slow for high volume delivery of chemical weapons. Ultimately, Iraq might have found investing in cruise missile technology to be far more productive for weapons delivery purposes, and using an aircraft-launched small boost to be a more cost-effective way of launching a satellite.

The Risk of Chemical Conflict

Iraq did not use chemical weapons in the Gulf War, or deploy such weapons forward to its forces in the KTO.[168] It did, however, threaten to use chemical weapons. Iraq also armed and dispersed tens of thousands of chemical artillery rounds and bombs, and provided its forces with chemical protection equipment. Searches of Iraqi headquarters, artillery, and field units in the KTO after the war found briefing materials and instructions which indicate that Iraq at least considered using mass fire of chemical weapons against the Coalition ground troops attacking its forward defensive barriers.[169]

Iraqi Chemical Weapons Programs at the Time of the Gulf War

Although Iraq was a signatory to the Geneva protocols of 1925, which prohibit the use of poison gas, this did not prevent it from producing and using chemical weapons in the Iran-Iraq War. Iraq started to produce mustard gas in small amounts at the laboratory level, and develop enough mass production capability so that it could make extensive use of mustard gas after 1984.[170]

While Mustard Gas is not an advanced gas agent, Iraq found that it offered significant military advantages in fighting Iran which might have applied to the Gulf War, and which may apply to future conflicts.[171] Mustard gas is a blistering agent which is 10 to 100 times less lethal than the simpler nerve agents in terms of direct exposure, and slow to act on those who are exposed.

Lethality, however, is not the only issue in measuring the effectiveness of chemical weapons. Like nerve gas, mustard gas attacks the lungs, eyes, and skin, and gas masks alone are not effective protection. Mustard gas is also easier to produce, handle, and deliver than nerve gas, and it can also be more effective than most nerve gases for several important tactical purposes. It persists for several days to several weeks, and its wounds are slow to heal. Exposed personnel that must work or operate in fixed areas and facilities are difficult to protect over long periods because chemical protection gear has a limited functional life. Exposures to mustard gas can blind or blister for periods of 4 to 6 weeks. Casualties consume large amounts of medical services and support.

These properties of mustard gas gave it considerable effectiveness against Iranian infantry, even though nerve gas did not produce high levels of fatalities. Iranian forces often spent considerable time in exposed locations and had relatively poor medical facilities. Their chemical protection gear was often of poor quality, and even the threat of gas often disrupted Iran’s operations.

However, Iraq did not stop at using mustard gas. It began to use small amounts of nerve gas in response to Iran's offensives in 1984. This nerve gas consisted of non-persistent "G-agents", principally Sarin (GB). Such nerve agents are lethal, and act almost instantly when the skin, eyes, and wet tissue of their victims are exposed. Nerve gases are difficult to detect, and troops require excellent protection and an antidote in order to prevent high casualties. G-agents also persist for only a few minutes to a few days, and normally allow an attacker relatively rapid tactical movement into exposed areas. In contrast, persistent agents like mustard gas and persistent nerve gas may remain lethal for several days to several weeks. Friendly troops can only operate in exposed areas if they have full protection, and occupy the area for only a limited amount of time. This is why persistent agents are better suited to fixed- targets like air bases and logistic centers, or defensive operations where they can be used against the rear areas of the enemy with only limited risk to friendly troops.[172]

Iraq was able to produce both mustard gas and nerve agents in quantity by 1985 or 1986, although its major plants did not reach full capacity production of either gas until the late 1980s.[173] UN inspectors examining a key Iraqi facility at Muthanna after the war estimated that it eventually reached a peak daily production capacity of 5 tons of mustard gas and 2.5 tons of Sarin. They found that Muthanna still had 225 tons of nerve agent, and 280 tons of mustard gas. According to some reports, this plant was the facility that developed nerve gas warheads for Iraq's long-range missiles.[174]

The UN found a number of other facilities after the war. Iraq completed construction of a special refinery and other gas warfare facilities at Fallujah -- about sixty-five kilometers northwest of Baghdad -- before the August, 1988 cease-fire in the Iran-Iraq War.[175] These facilities were used to produce precursors like phosphorous trichloride, phosphorous chloride, and thionyl chloride, and to store chemical weapons stocks.[176] Iraq may also have produced some persistent VX nerve gas at this facility.[177]

Iraq had a plant near Basra designed to produce 410,000 tons of ethylene products a year. Iraq began construction of a new Petrochemical Complex No. 2 ethylene plant near Musayyib in 1988, which was scheduled to begin operations in 1991.[178] The Musayyib facility was designed to produce 420,000 tons of ethylene, and 67,000 tons of ethylene oxide.[179]

Iraq expanded its phosphate industry, which is centered at Akashat and Al-Qaim, and seemed to have adapted powdered detergent and fertilizer plants using phosphate ore to produce feedstocks. Iraq expanded its facility at Rutbah, just south of Ashkhat, to produce acids and other chemical components. It may have established a complex called "Project 9320" in the area, which had three factories to produce secondary chemicals used in manufacturing nerve gas.[180]

Some analysts estimate that these developments allowed Iraq to expand its production of all types of poison gas from about 10 tons a month by late 1985, to over 50 tons per month by late 1986.[181] Iraq may have been able to produce over 60 tons of mustard gas a month and four tons each of Tabun and Sarin by late 1987, and over 70 tons of mustard gas a month and six tons each of Tabun and Sarin by mid-1988.[182] These totals do not include possible production of Soman, a choking agent like phosgene, blood agents like hydrogen cyanide and cyanogen cyanide, vesicants like Lewisite, and agents like Adamsite and Chloropicrin.[183] The possible range of Iraqi chemical weapons is shown in Table 11.4, although most documented Iraqi uses of chemical weapons involved only the use of mustard gas and non-persistent nerve gas.

Iraqi production continued to expand until the beginning of the Gulf War. According to some estimates, Iraq had at least ten major storage bunkers for chemical weapons scattered throughout Iraq by the time Desert Storm began. These estimates indicate that Iraq was able to produce up to 3,500 tons of mustard gas, and 2,000 tons of Sarin and Tabun a year by 1989 -- or more than 20 times the amount it could produce in 1985. They also indicate that Iraq was producing persistent agents VX and VR-55, and that its plant at Fallujah was being expanded to a capacity of 2,000 tons per month.[184] Such a level of production would have given Iraq enough chemical agents to arm 250,000 - 500,000 tube and rocket artillery rounds a year, as well as smaller numbers of bombs, although such estimates may sharply exaggerate Iraq's capabilities.[185]

Iraq also did not halt its use of poison gas with the end of the Iran-Iraq War. It used poison gas regularly between 1988 and 1989, as part of its military effort to suppress Kurdish military resistance. This use was confirmed by a British defense laboratory that tested soil and bomb damage fragments taken from Kurdish villages in the north of Iraq. The Chemical and biological defense establishment at Porton Down found low levels of sulfur mustard gas and Sarin (GB). These traces were found in Birjinni, a village of about 200 in northern Iraq. This village had been selected because eyewitnesses had said that Iraqi planes dropped three clusters of four chemical bombs on August 25, 1988, and killed at least four people.[186]

Iraq did, however, put more effort into increasing its volume of production than into making its chemical weapons effective. Most of the designs the UN found after the Gulf War had only limited dispersal capability, reliability, and storage problems, and limits to their fusing that affected the ability to reliably set height of burst. Iraq did not have binary nerve gas. Saddam Hussein stated on April 2, 1990, that Iraq had "double-combined chemical" weapons, and had them since the last year of the Iran-Iraq War. Such weapons later proved to be a crude technology for storing alcohol in nerve gas weapons that it acquired in 1984 or 1985, and used during the latter half of the Iran-Iraq War.

There were several other chemical weapons technologies that Iraq seemed to have been ready to deploy when the Gulf War began.[187] It did not have "dusty" mustard gas that overcomes defenses in a different way. "Dusty" mustard gas is a powdered form of Mustard gas which is very persistent, and which can coat particles so small that they are only several microns in size and which may be able to penetrate protective clothing and filters. Iraq also does not seem to have had "cocktail" chemical weapons which mix several chemical agents together to provide different kinds of lethality and/or defeat different forms of protection including many gas masks. While some sources indicate that Iraq used "cocktails" of cyanogen with mustard gas and Tabun in Kurdistan, this has not been confirmed.[188]

Iraqi forces did, however, have considerable readiness for chemical warfare at the time they invaded Kuwait. Since 1985, Iraqi doctrine had called for the regular training of all combined arms elements in chemical warfare. Iraqi forces in the KTO were equipped with numerous dual-capable delivery systems, and sophisticated chemical protection, reconnaissance, and decontamination gear. Delivery systems included rifle grenades, 81mm mortars; 152mm, 130mm, and 122mm artillery rounds; bombs, bomblets, 90 mm air-to-ground rockets, 216 kilogram Frog and 555 kilogram Scud warheads, and possibly land mines, and cruise missiles. As many as 50% of Iraq's combat aircraft and artillery weapons could deliver chemical rounds.[189] Its units were equipped with chemical protection and decontamination gear, and with the operational instructions for using chemical weapons.[190]

While Iraqi regular army and air force units were tasked with delivering the chemical weapons, Iraq had special chemical troops integrated throughout all of the branches of the Iraqi armed forces which were responsible for the care, build-up, and delivery of chemical weapons. They had a status approaching that of a separate combat arm, and included units and sub-units responsible for chemical defense, radiation and chemical reconnaissance, the operation of smoke and flame generators, the identification of chemical targets and meteorological analysis, and decontamination. Each corps had a chemical battalion, each independent brigade or division had a chemical company, regiments had chemical platoons, and chemical sections were assigned to battalions or platoons with weapons capable of delivering chemical weapons.[191]

Table 11.4

Chemical Agents that Iraq Now Has The Technical Capacity To Produce

Type of agent	Delivery Method	Symptoms	Effects	rate of action
Confirmed				
Blistering- Mustard (possibly Dusty Spray, Mustard)	Missile, Artillery, Bomb, aerial Types; Land mine Stinging of Skin	No early Symptoms for Mustard Searing of eyes, Blindness	Blisters skin, Minutes Destroys Respiratory Tract, causes Temporary	
Nerve- Missile, Sarin (GB), Tabun (GB), VK/VX?	Difficult Artillery, Bomb, aerial Spray, Land mine Convulsions	Incapacitates Breathing, Drooling, Nausea, Vomiting,	Seconds Or kills when Delivered in High Concentrations	
Suspected in at least limited amounts				
Blood - Cyanide	Missile, Artillery, Bomb	Convulsions and coma High Concentrations	Incapacitates Or kills when Delivered in	Minutes
Possible at experimental level				
Choking - Phosgene	Missile, Artillery, Bomb Headache	Coughing, Choking, Nausea,	Damages and Floods lungs	Hours

Source: James Blackwell, Thunder In The Desert, New York, Bantam, 1990, p. 35; Dick Palowski, Changes In Threat Air Combat Doctrine And Force Structure, 24th Edition, Fort Worth, General Dynamics DWIC-01, February, 1992, pp. II-336 To II-338; Us Department Of Defense, Conduct Of The Persian Gulf War: Final Report, Department Of Defense, April, 1992, Pp. 16-18.

Counterproliferation: The Coalition Effort to Attack Iraqi Chemical Weapons

This threat explains why the Coalition launched a total of 970 air and missile strikes against Iraqi chemical, biological, and nuclear facilities during the Gulf War. About 80% of these strikes used precision weapons, and 40% were carried out by F-117s. The non-precision strikes were made largely by B-52s, F-16s, F/A-18s, GR.1s, F-111Es, and A-6Es; a few were made by F-111Fs and F-15Es. Figure 11.2 shows that these strikes were made in cycles, with a heavy peak of strikes during the first week of Desert Storm, a lull during the following few days and then periods of 10-20 strikes per day with occasional peaks. About 54% of the strikes were made during the day, and 46% were made at night.[192]

These strikes undoubtedly had some effect on Iraq's chemical weapons production capabilities. They struck at the three redundant chemical precursor facilities near Fallujah, at the research centers like Salman Pak (which was also associated with biological toxins), and chemical production plants like Samara. They struck at a number of suspected storage sites throughout Iraq, at the special "S" and cruciform-shaped shelters near Iraqi air bases, and at storage facilities in Kuwait. Suspected delivery systems like the Tu-16 Badger bombers at Al Taquaddum were struck during the second week of the war.[193]

These attacks severely damaged Iraqi chemical warfare production capabilities, although UN inspections later found that they did far less damage to Iraqi production capability than USCENTAF planners originally estimated, because physical damage to a building did not mean proper characterization of the target or massive physical damage to key production equipment. The US concluded after the war, that it needed much more lethal weapons to hit hard and underground facilities, and more sophisticated technologies for characterizing the internal layout of large scale manufacturing facilities. It is now giving new warhead technologies for destroying underground chemical, biological, and nuclear capabilities a high priority, as well as examining ways to improve lethality against the manufacturing equipment inside a plant as distinguished from damaging the building.[194]

Strategic bombing reduced Iraq's ability to move its weapons south, destroyed some of its artillery forces, and its ability to use offensive air power. It did little, however, to destroy Iraq's chemical weapons and scarcely paralyzed its chemical warfare capabilities. Iraq had ample stocks of chemical weapons. The size of Iraq's surviving gas warfare capabilities is indicated by the stocks the UN recovered after the war. Iraq initially declared to the UN that it had 500-550 metric tons of mustard gas and nerve agents in April, 1991. It increased this total to 650 metric tons in may, and to over 700 metric tons in July.

To illustrate the scale of Iraq's effort to deceive the UN inspectors, it initially declared only 105 155mm artillery shells filled with mustard gas, although the UN eventually found 12,634.[195] The UN went on to find 355 tons of mustard gas and nerve agents, 650 tons of intermediate chemicals, 6,920 chemical filled rocket warheads, and 1,376 aerial bombs.[196] Many of the munitions that the UN found were stored at the Al-Muthanna State establishment mentioned earlier. This is a 25 square kilometer complex about 100 kilometers north of Baghdad, and near the air base at Habbaniyah. Large numbers of chemical weapons were also found at four other sites, known as Fallujah 1, Fallujah 2, Fallujah 3, and Muhammediyat Stores.

As of February, 1992, the UN had found 45,755 filled chemical munitions versus the 10,000 to 11,000 that Iraq had initially declared, 78,675 unfilled munitions, 355 tons of bulk agent, and 3,173 tons of precursors for chemical weapons versus the 650 tons that Iraq had originally declared. UN and US sources estimated that Iraq might still be concealing up to 50,000 more rounds than it declared.[197]

The primary threat to Coalition ground troops consisted of Iraqi's artillery shells. The principal shell with the 155mm round. Each was filled with 3.5 liters of mustard agent using a tetyl burster charge. In addition to the 155mm artillery shells, the UN found 20,000 120mm mortar bombs filled with non-lethal CS gas. (Many damaged in the Coalition bombing). There were some experimental conversions of 130mm and 152mm smoke shells, and roughly 10,000 122mm rocket rounds filled with between 6.4 and 9 liters of nerve gas. These rocket rounds were poorly designed, and corroded by a combination of the effects of the gas and decomposition of the solid fuel rocket motor.

The UN found bombs filled with mustard gas, and two types of nerve gas. While the mustard gas weapons were of adequate design quality -- and had been damaged largely by mishandling and poor storage -- the nerve agents had quality problems. They consisted of GB (Sarin), GF, or a mixture of the two. They were chemically unstable, and soon broke down into lethal compounds. As a result, Iraq produced GB in batches, and only loaded its nerve gas weapons a few days before their use. The UN confirmed that Iraq's "binary weapons" were relatively crude. They were not storable binary weapons with agents kept in the bomb and automatically mixed. The bombs were prefilled with suitable alcohols, which then had to be manually added and stirred. Such a procedure is dangerous for the operator, and can lead to improper mixture of the agent.

Iraq had four main types of chemical bombs. The smallest was the LD-250, a modification of a Spanish 250-pound smoke bomb. Each LD-250 normally carried 64 liters of mustard gas, and the UN found 915 bombs filled with mustard gas -- although Iraq had declared total of 110. There were also some 250 bombs filled with CS gas, but the UN did not find such weapons in significant numbers. Iraq had a 500 pound bomb called the Aald-500. This contained 150 liters of mustard gas, and the UN found 676 such weapons. There were two bombs using nerve gas. One was the DB-2, which contained 400 liters of GB. The other was the R-400, which contained 102 liters of binary GB. The UN found 336 bombs of this type.

The US estimated during the war that Iraq had some MiG-21 derived drones that could be used to deliver chemical weapons. These systems were not found after the war, but the UN inspectors found that Iraq had produced 50 warheads for the Al-Hussein missile.[198] Nine had been destroyed in static testing and 11 had been used in training. The UN found that the remaining warheads had left in an orchard near a road. Sixteen of the 30 remaining warheads had unitary GB warheads, and 14 were of the binary type. The binary warheads were partially filled with alcohol to allow them to be armed by adding DF. The warheads were poorly welded, had generally poor construction, and the burster charge was badly placed. It is uncertain whether such warheads could have done any real damage, and some experts feel that they might have tumbled and broken up on reentry.

Finally, the UN found 300 tons of bulk agent stored in containers ranging from barrels to large tanks. Most of this agent was Mustard gas, but at least 35 tons was GB. Much of the GB had broken down in storage. The UN found 2,579 tons of precursors out of the 3,173 tons that Iraq had declared. It is possible that much of this total spilled or evaporated, but it is uncertain what happened to the remainder.[199]

The UN investigations did show, however, that Iraq had more problems because it had failed to keep its agents pure, and to develop corrosion-proof materials, than it did with the Coalition bombing effort. Nearly 25% of the weapons that the UN found had leaked, although it was often impossible to distinguish between problems with the chemical agents, problems with the weapons design, and problems because of wartime damage or rapid post-war movement and inadequate storage.[200]

Part of the reason that the Coalition strikes failed to destroy these weapons lay in the fact that US intelligence experts assumed that Iraq would be very careful to main tight control of the weapons and would have special security arrangements to protect them. In fact, none of the Iraqi chemical weapons had of any kind of special markings, and the UN inspectors found chemical and conventional bombs stored together at Kadzir air base. Other weapons were dispersed outside plants and storage facilities and coverage with loose earth, providing none of the target signatures that intelligence experts expected.

Figure 11.2

Coalition Strikes/Sorties Against Nuclear, Biological, and Chemical (NBC) Targets

Source: Eliot Cohen, ed., Gulf War Air Power Survey, Volume II, Part II, p. 324.

Iraq's Decision Not To Use Chemical Weapons

There is no way to determine why Iraq did not use its chemical warfare capabilities during the Gulf War without having access to the thoughts and intentions of Iraq's senior leadership.[201] Iraq certainly made threats to use chemical weapons in dealing with the Western and Arab reaction to its invasion of Kuwait and build-up on the Saudi border soon after it invaded Kuwait. For example, Saddam Hussein gave a speech on August 20, 1990, stating that foreign hostages would be dispersed to military and key civil locations throughout Iraq, including Iraq's major chemical weapons production facilities. Iraq also made demonstrative gestures. It conspicuously loaded its aircraft with chemical weapons so that this could be detected by US intelligence before removing the weapons and placing them in back in their normal storage sites.

During the fall of 1990, Iraq dispersed chemical weapons in a number of rear area facilities. By November, 1990, Iraq had built up large dispersed and sheltered stocks of chemical weapons in its territory outside the Kuwaiti Theater of Operations (KTO). It deployed a wide range of chemical-capable delivery systems in its forces supporting its invasion of Kuwait. It also deployed protection and decontamination gear, issued detailed instructions on chemical warfare to its unit commanders, and built decontamination trenches in the forward and rear areas.[202] Iraq also clearly retained large stockpiles of weapons until well after the end of the war.

At the same time, Iraq faced many problems in using its chemical weapons. These problems included (a) the purity and storage problems discussed earlier (Iraqi nerve agents were not purified and were not stable in hot weather, they were normally stored in cooled bunkers with instructions that they be used within a week of removal) (b) Iraqi fear of Coalition or Israeli retaliation with nuclear or chemical weapons (c) the shattering impact of coalition bombing (d) the fact Iraq quickly lost much of its command and control and distribution capability and (e) poor weather conditions during the ground campaign where winds and rain made effective use of chemical weapons very difficult.

All of these factors may have had a significant impact on Iraq's leadership. Given Iraq's past willingness to use chemical weapons against Iran and the Kurds, the deciding factor may have been the Coalition and Israel's ability to retaliate. The first few days of the Coalition air campaign showed Iraq that the Coalition could expand its conventional strategic bombing campaign to far more devastating levels by attacking key commercial and government targets. This experience gave Iraq's leadership good cause to fear that such escalation might lead to more intensive Coalition air attacks and to a UN effort to drive them from power.

At the same time, there is no way to know the extent to which Iraq's leadership also feared the nuclear threat posed by Israel and the US. And, there is no way to determine the impact of the technical and operational problems that Iraq faced. None of the problems in employing chemical were compete "war stoppers," but they were serious and they well may have had an impact on Iraqi decision-making. [203]

The Possible Impact of Iraqi Use of Chemical Weapons at the Tactical Level[204]

The preceding analysis has shown that Coalition forces would have had serious problems if Iraq had decided to use chemical weapons. Table 11.5 illustrates the kind of damage chemical weapons can inflict if they are well-designed and effectively employed. It is clear from this table that such threats are scarcely ones it is wise to ignore.

At the same time, the preceding analysis also shows that Iraq would have faced serious operational problems in using chemical weapons at either the tactical or strategic level. Iraq's experience during the Iran-Iraq War did not prepare it for effective operations at the tactical level. While Iraq made effective use of chemical weapons against Iran during 1987-1988, its tactics depended heavily on massed fire against concentrated and relatively static Iranian ground troops with only limited chemical protection gear. It was most successful when it used chemical weapons against massing Iranian attackers that had little maneuverability, or massing Iranian defenders that had little other option other than retreat. It also was more successful in using chemical weapons as a terror weapon than a killing weapon.

Iraq lost air superiority so early in the war that it would have had little capability to deliver chemical weapons by air, and could not have massed enough aircraft over any part of the battlefield at any time to pose a significant threat to Coalition ground troops or rear areas. As Chapters Eight and Nine have shown, Iraq also faced serious problems in making effective use of its artillery. Coalition air attacks battered Iraqi forward positions for weeks before Coalition ground troops advanced. By the time, the Coalition breached Iraq's forward defenses, Iraqi divisions had taken serious equipment losses, had major supply problems, and suffered from high levels of desertion. Many Iraqi artillery weapons had been damaged or destroyed.

If Iraq had used chemical weapons to augment its forward defenses, this might have delayed the Coalition advance in some areas. Not all Coalition troops had effective chemical protection gear -- at least in terms of reliable detection, decontamination, and facility protection equipment. The Coalition troops sent forward did, however, generally have adequate personal protection gear. The Coalition also generally crossed through Iraq's defenses very quickly and did not halt and mass in the forward area. In most cases, their rapid rate of advance would have penetrated and overrun Iraq's artillery before chemical weapons could have had a major tactical effect. Most Iraqi forces in the forward area also lacked the tactical cohesion to use chemical weapons in mass, and exploit them for either defense or counterattacks.

Iraq would have experienced special problems in dealing with the thrusts of the Coalition armored attack. The US XVIII Corps and VII Corps moved against Iraq from a direction where it had not prepared extensive forward defenses, and had little massed fire capability. The British, French, and US forces in both Corps also had adequate chemical protection gear. Iraq, at best, would have had limited capability against the most effective forces in the Coalition ground offensive.

Iraq was not organized to use chemical weapons effectively in rear areas or at the theater level once the land battle penetrated its forward defenses and became a fluid war of maneuver. It had no ability to mass chemical artillery fire quickly in most rear areas. Iraq had limited target acquisition capability against maneuvering forces. Coalition armored and heliborne troops had the initiative and overran Iraqi positions before more than limited chemical defense fire could take place. This was particularly true of the Coalition forces attacking from the west, and Coalition forces were sometimes slower in driving north through Kuwait towards Kuwait City.

This does not mean that a major Iraqi attempt to use chemical weapons would not have significantly raised Coalition casualties or had limited tactical successes. Coalition forces like the Egyptian divisions that delayed at Iraq's forward defenses did make good targets. Units that delayed to regroup or secure their flanks, like a number of the Arab units, exposed themselves to chemical attack. Even limited amounts of fire on British and US armor might have led to some additional delays for decontamination, or to further delays in the double envelopment movement. Use of persistent nerve gas and mustard gas might have affected some Coalition support and supply movements.

The Possible Impact of Iraqi Use of Chemical Weapons at the Strategic Level

Iraq did not attempt to use chemical weapons at the strategic level. It did not launch long range strike aircraft attacks armed with chemical bombs, although it had the capacity to attempt such strikes. It did not fire missiles with chemical warheads at Coalition or Israeli targets, although it did have such warheads.[205] It is important to point out, however, that a lucky Scud hit near Dhahran scored Iraq's only major strike against US forces -- and killed 28 US Soldiers and wounded 97 others. This Scud strike not only was Iraq's only long-range offensive success of the war, it killed more Coalition soldiers than any single land engagement of the war, and Iraq's missile attacks on Israel damaged a number of urban areas, caused additional civilian casualties, and achieved world-wide publicity.

Iraq's missile strikes might have had far more impact if it had used chemical warheads -- particularly if it had fired in volleys -- although UN inspectors found after the war that Iraq's chemical warheads were relatively crude and unreliable. Soviet technicians who inspected the Iraqi missiles felt that much of the basic missile modification work was also crude, which explained the break-up of many Iraqi modified Scuds during their approach towards targets in Israel. They also felt that the chemical warheads were unbalanced, and would have made these problems far worse -- potentially making the warheads burn up or depriving them of much of their effectiveness.[206]

Table 11.5

Typical Warfighting Uses of Chemical Weapons

Mission	Quantity
Attack an infantry position: Cover 1.3 square kilometers of territory with a "surprise dosage" attack of Sarin to kill 50% of exposed troops.	216 240mm rockets (e.g. delivered by 18, 12 tube Soviet BM-24 rocket launchers, each carrying 8 kilograms of agent and totaling 1,728 kilograms of agent.
Prevent launch of enemy mobile missiles: Contaminate a 25 square kilometer missile unit operating area with 0.3 tons of a persistent nerve gas like VX per square kilometer.	8 MiG-23 or 4 Su-24 fighters, each delivering 0.9 ton of VX (totaling 7.2 tons.)
Immobilize an air base: Contaminate a 2 square kilometer air base with 0.3 tons of VX twice a day for 3 days.	1 MiG-23 with six sorties or any similar attack aircraft.
Defend a broad front against large scale attack: Maintain a 300 meter deep strip of VX contamination in a front of a position defending a 60 kilometer wide area for 3 days.	65 metric tons of agent delivered by approximately 13,000 155-mm artillery rounds.
Terrorize population: Kill approximately 125,000 unprotected civilians in a densely populated (10,000 square kilometer) city.	8 MiG-23 or 4 Su-24 fighters, each delivering 0.9 ton of VX (totaling 7.2 tons) under optimum conditions.

Source: Adapted from Victor A. Utgoff, The Challenge of Chemical Weapons, New York, St. Martin's, 1991, pp. 238-242 and Office of Technology Assessment, Proliferation of Weapons of Mass Destruction: Assessing the Risks, US Congress OTA-ISC-559, Washington, August, 1993, pp. 56-57.

Iraq's Future Chemical Weapons Capabilities

US reporting on the bombing effort during the Gulf War has sometimes left the impression that Iraq had little chemical production capability at the time of the cease-fire. For example, the Department of Defense study of the lessons of the war claims that,[207]

> "At least 75% of Iraq's CW production capability was destroyed. At Samara, Coalition forces destroyed or severely damaged most known primary CW production, processing, or production support buildings. All three buildings used to fill munitions at Samara were destroyed, although the Iraqis may have moved the equipment from one building before Desert Storm for safekeeping. All three precursor chemical facilities at Habbaniyah were seriously damaged. Although Iraq previously had produced and distributed many CW agents to storage sites throughout the country, the means for delivering these weapons was badly damaged. Coalition air supremacy made Iraqi Air Force delivery of these weapons unlikely; most artillery (Iraq's preferred method of delivering CW) was disabled."

These is no doubt that the Coalition damaged many key Iraqi facilities. The UN inspection effort since the war has also discovered and destroyed a great deal of additional Iraqi chemical weapons and production equipment, including items like the production equipment concealed in a milk plant near Mosul. Nevertheless, Iraq had ample time to disperse many of its precursors and key production sub-systems before the Gulf War began, and continued to hide and disperse them after it signed a cease-fire.[208]

Many experts feel that Iraq has retained the capacity to build significant stocks of weapons. Robert Gates, a former Director of Central Intelligence, testified to Congress in early 1992, that much of Iraq's "hard to get production equipment" for chemical weapons had been dispersed and "hidden" before the allied bombing attacks. He also estimated that, "if UN sanctions are relaxed, we believe Iraq could produce modest quantities of chemical agents almost immediately, but it would take a year or more to recover the chemical weapons capability it previously enjoyed."[209]

Other experts feel Gates exaggerated the ease with which Iraq could acquire a significant chemical capability and that it might take several years and several hundred million dollars worth of imported equipment to develop a major war fighting capability. They note that Iraq lost much of its feedstock production capability during the bombing of Samara -- which was very heavily hit during the war. The difference between these views, however, is a matter of a relatively few years, and may be one of definition. The large amounts of gas needed to support a major land offensive are very different from the comparatively limited amounts needed to arm several hundred missile warheads and aircraft bombs.

Iraq will almost certainly be able to recover significant near-term capability to threaten enemy population centers and area targets with missile and air strikes within a relatively short time after it is freed from UN control.[210] Iraq will probably take three to five years to recover a significant capability to use chemical agents in enough shells, rockets, bombs, and warheads to fight a major land war once UN controls are lifted. It has lost a significant amount of its production capability, and will initially be limited to laboratory or small batch production. This still, however, will allow a nation as advanced as Iraq to covertly produce several hundred gas weapons -- including missile warheads. There is virtually no way that any current inspection and control regime can prevent this.

Lessons For Future Conflicts

There are obvious dangers in generalizing on the basis of potential capabilities. Nevertheless, the Coalition's problems in depriving Iraq of its Scuds, other delivery means, and chemical weapons stocks have implications for the future. While each potential threat country must be treated as a specific case study, there seem to be lessons that are likely to apply to Iraq as a future threat and to other chemically armed powers like Iran and North Korea:

o The US, other Western nations, and any Coalition force engaged in conflict with a chemical power must be fully ready to deal with the risk of chemical warfare. There is no way to predict whether a nation will engage in chemical warfare, what mix of targets it will choose, and what level of escalation it will be willing to risk.

o The forces deployed must be capable of operating in a chemical environment. This not only means providing superior personal protection gear, it means providing modern detection gear, gear that provides safe work areas, and decontamination gear. Forces must also plan for more lethal agents like dusty mustard gas and persistent nerve agents.

o Rear area facilities must be protected to the extent that they are capable of functioning in the face of chemical attack. Air bases, key logistics and reception sites, and other areas involving heavy troops concentrations will require special attention.

o Power projection forces must be prepared for mobile warfare and operations in-depth to reduce vulnerability to chemical warfare. They must be capable of rapid dispersal.

o Active air and missile defenses may be needed to protect both military forces and key civilian areas.

o Defense is not likely to be enough in most cases. A deterrent and retaliatory offensive capability will be needed to reduce the risk of use and exact penalties for such use. Ideally, this should take the form of conventional strike options which can be kept separate from the rest of the conflict and which can be linked to non-use or use.

o Such a retaliatory capability may be needed for both nations projecting power and nations in the region around proliferators. A strong regional conventional retaliatory capability is likely to increase the willingness of friendly states to resist intimidation and support power projection efforts, it is likely to help deter the future use of chemical weapons, and it is likely to reduce the risk that friendly or moderate states will develop their own weapons of mass destruction as a counter to the actions of aggressor states like Iraq.

o Counterproliferation is not likely to deprive a nation of chemical strike options in the near future. While it may be possible to develop greatly improved strike plans for use against key threat nations, and improved sensors and intelligence collection methods, it is also possible for threat states to develop launch under attack capabilities and improved methods of forward dispersal. Nevertheless, counterproliferation capabilities should be improved at least to the point where a potential user faces the risk of losing a substantial amount of its chemical capability.

o Controls on technology transfer and feedstocks, and attempts to enforce arms control agreements like the Chemical Weapons Convention are unlikely to prevent further proliferation or prevent existing proliferators from improving their current capabilities. They can, however, limit the rate and quality of proliferation and every means should be used to make export controls and arms control agreements effective in limiting the threat.

None of these lessons is sufficient by itself to deal with the threat posed by chemical weapons, and acting upon them may not prove cost-effective in given cases. A well-chosen mix of such actions may, however, help to confront other states with the same problems faced by Iraq. They do not provide any guarantee of deterrence or of eliminating serious casualties. They do, however, offer a much better prospect of future security than no action, and no state can count on the same level of strategic warning or air supremacy in the future that the Coalition enjoyed during the Gulf War.

The Risk of Biological Warfare

It is far harder to document the history of Iraq's efforts to develop biological weapons than to document its efforts to develop chemical and nuclear weapons. This often leads to a neglect of Iraq's capabilities in this area, although there have been some highly controversial charges that Iraq has used mycotoxins against its Kurdish population since early in the Iran-Iraq War that have never been confirmed.[211] Most of the examples and symptoms cited in such charges can be explained more easily by the poor sanitary and health conditions affecting the population in the area. The use of mycotoxins or "Yellow rain" weapons cannot be ruled out, but reports that the Iraqi secret service used Biological agents or Toxins to poison the food in Kurdish refugee camps in mid-1989, and produce 700 dead and 4,000 casualties, seem dubious.[212]

Iraqi Biological Warfare Facilities

Iraq has strongly denied developing biological weapons as well as reports that it has used them against the Kurds.[213] Virtually all Western experts agree, however, that Iraq began working on biological weapons in the 1970s, conducted extensive research on mycotoxins beginning in the mid-1980s and was producing some aspect of biological weapons at least four different facilities when the Gulf War began.[214]

There not only are strong indications that Iraq has produced agents like botulin, anthrax, and clostridium perfingens -- but that it has conducted research into typhoid, cholera, tularemia, and equine encephalitis.[215] After the Gulf War, indications surfaced that Iraq was conducting weapons research at the Biological Research Centre of the Scientific Research Council in Baghdad and the Nuclear Research Institute of the Atomic Energy Commission in Tuwaitha -- which housed one of the leading biological research laboratories in Iraq. Salman Pak seemed to have been a major center for the development and production of Biological weapons, as well as chemical weapons. Work also seemed to have been done by the Genetic Engineering and Biotechnology Research Center in Baghdad, which is part of the Scientific Research Council. Iraq established this genetic engineering and biotechnology research center shortly after the Iran-Iraq War, and was one of the first nations to ratify a UN agreement setting up international centers for such research in Triest, Italy and New Dehli, India. Facilities also seem to have existed at Al-Kindi, Taji (north of Baghdad), and Al- Hakim. [216]

Some of Iraq's biological warfare production facilities may have been co-located with industrial plants. The Iraqi Ministry of Industry and Military Industrialization created a State Enterprise for Drug Industries at Samara which consolidated plants originally built with Soviet assistance, but which later benefited from East German and West German support. Iraq also established a research laboratory for the State Enterprise for Drug Industries which was located in close proximity with the Iraqi State company for pesticide production.[217]

Other facilities included a plant near Al-Latifiyah, two plants near Abu Ghurayb, and the Al-Kindi Company for Serum and Vaccine Production, and a major French-designed factory for manufacturing the vaccine for hoof and mouth disease at Doura, Baghdad. Some reports indicate that this plant could make up to 12 million doses per year, and had a research effort designed to allow it to manufacture up to 15 different vaccines. They included a production facility at Taji and the Arab company for antibiotic industries in Baghdad -- an Iraqi-Jordanian-Saudi government-owned firm that is building a factory capable of make 200 tons of penicillin a year. This latter project received extensive support from a German firm called V-Consult Ingenieur.[218]

There are reports that Iraq acquired mobile toxicological laboratories from German companies. These laboratories theoretically are for "agricultural chemistry" but the German firms involved in supplying them include Karl Kolb, a firm that actively helped Iraq acquire chemical weapons.[219] Further, German firms called Josef Kuhn and Plato-Kuehn seem to have sold Iraq 2.7 grams of mycotoxins called T-2 and HT-2, which it acquired from their parent US firm, Sigma Chemie.[220] The US State Department has charged that these are the same toxins that Vietnam used in Cambodia and the Former Soviet Union used in Afghanistan. Sigma Chemie is also reported to have transferred precursor viruses for biological weapons, and Iraq seemed to have obtained the strains for a number of viruses that can be used for Biological warfare from centers in the US, under the guise of requesting them for medical research.[221]

Iraq has long maintained and established tight censorship over any discussion of these facilities, and many aspects of its biological research efforts. Iraq seems to have prevented any unclassified publications on anthrax and Botulinum neurotoxins after the late 1970s. A post-war study found one Iraq article on each area during the entire period from 1969 to 1991, although Anthrax is a potential health hazard in Iraq. Similarly, no Iraqi research was published on Tularemia and West Nile fever, although Iraq acquired the cultures for these diseases, as well as 17 shipments of cultures of various toxins and bacteria from the American Type Culture collection during the period between 1985 and 1991.[222]

Possible Iraqi Biological Agents

There is no reliable way to determine the specific biological weapons that Iraq was developing before the Gulf War, although the head of the British government's defense arms control unit, Peter Verker, has stated that, "biological research activities for military purposes had been undertaken at Salman Pak since 1986, and included research into some of the most effective biological agents -- the organisms which cause gas gangrene (Clostridium perfringens), anthrax, (Bacillus anthracis), and botulism (Clostridium Botulinum)."[223]

UN inspection teams found some indications of brucellosis and tularemia research once the Gulf War was over.[224] Other logical Iraqi biological weapons efforts include equine encephalitis, enterotoxins, and possibly cholera and typhoid. Iraq seems to have had weapons production facilities at Salman Pak, and at least some stock piles of toxins and stable weapons like anthrax. It is also clear that Iraq had at least three to six other biological warfare sites, and probably had a number of other storage facilities.

The spectrum of possible biological weapons or agents is shown in Table 11.6. It is important to note several aspects of this table that may have important lessons for the future:[225]

- o First, many forms of biological weapons are not lethal to humans. Biological warfare can be used in forms that may kill or incapacitate.
- o Second, some biological weapons only become effective long after they are delivered. This makes covert delivery attractive since a target country would only detect symptoms once the disease became effective, and might find it impossible to prove the source of the weapon.
- o Third, no cure or treatment exists for a number of agents, and most protection systems and cures are disease specific. This makes it almost impossible to prepare effective defenses and treatments.
- o Fourth, no current detection or warning system exists for most of the agents listed in Table 11.6. There are promising technologies that may provide such capabilities, but none are yet proved to be reliable or available in the field.
- o Fifth, biological agents normally are not the source of communicable disease, and do not present the risk of epidemics or uncontrollable expansion of the disease. As a result, some can be used with considerable safety.
- o Sixth, as a nation's technical capabilities expand, it can "tailor" a given disease or agent to produce a wide range of effects in terms of lethality, survival of the agent, period of effectiveness, etc. Further, it can reduce the risks that it runs in using highly lethal agents, and improve its ability to both produce weapons in small facilities, and to produce dry storable weapons that can be microencapsulated and stored in dispersed facilities. Time is on the side of the proliferator.
- o Seventh, as technical capabilities to produce agents improve, so do capabilities to weaponize an agent in many different forms, and to develop bombs, warheads, and devices that are more effective.

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Table 11.6

Key Biological Weapons That Iran And Iraq Might Weaponize: Part One

Disease	Infectivity	Transmissibility	Incubation Period	Mortality	Therapy
Viral					
Chikungunya fever	High?	None	2-6 days	Very low (-1%)	None
Dengue fever	High	None	5-2 days	Very low (-1%)	None
Eastern equine encephalitis	High	None	5-10 days	High (+60%)	Developmental
Tick borne encephalitis	High	None	1-2 weeks	Up to 30%	Developmental
Venezuelan equine encephalitis	High	None	2-5 days	Low (-1%)	Developmental
Hepatitis a	-	-	15-40 days	-	-
Hepatitis b	-	-	40-150 days	-	-
Influenza	High	None	1-3 days	Usually low	Available
Yellow fever	High	None	3-6 days	Up to 40%	Available
Smallpox (variola)	High	High	7-16 days	Up to 30%	Available
Rickettsial					
Coxiella burneti (q-fever)	High	Negligible	10-21 day	Low (-1%)	Antibiotic
Mooseri	-	-	6-14 days	-	-
Prowazeki	-	-	6-15 days	-	-
Psittacosis	High	Moderate-high	4-15 days	Mod-high	Antibiotic
Rickettsi (rocky mountain Spotted fever)	High	None	3-10 days	Up to 80%	Antibiotic
Tsutsugamushi	-	-	-	-	-
Epidemic typhus	High	None	6-15 days	Up to 70%	Antibiotic/ Vaccine
Bacterial					
Anthrax (pulmonary)	Mod-high	Negligible	1-5 days	Usually fatal	Antibiotic/ Vaccine

Brucellosis	High	None	1-3 days	-25%	Antibiotic
Cholera Low	High 1-5 days	Up to 80%	Antibiotic/		
			Vaccine		
Glanders	High None	2-1 days	Usually fatal	Poor antibiotic	
Meloidosis	High	None	1-5 days	Usually fatal	Moderate
antibiotic					
Plague (pneumonic)	High	High	2-5 days	Usually fatal	Antibiotic/
			Vaccine		
Tularemia	High Negligible	1-10 days	Low to 60%	Antibiotic/	
			Vaccine		
Typhoid fever	Mod-high	Moderate-high	7-21 days	Up to 10%	Antibiotic/
			Vaccine		
Dysentery	High High	1-4 days	Low to high	Antibiotic/	
			Vaccine		

Table 11.6

Key Biological Weapons That Iran And Iraq Might Weaponize: Part Two

Disease	Infectivity	Transmissibility	Incubation Period	Mortality	Therapy
Fungal					
Coccidioidomycosis	High	None	1-3 days	Low	None
Coccidiodes immitis	High	None	10-21 days	Low	None
Histoplasma Capsulatum	-	-	15-18 days	-	-
Norcardia asteroides	-	-	-	-	-
Toxins[a]					
Botulinum toxin	High	None	12-72 hours	High neromusc- Lar paralysis	Vaccine
Mycotoxin	High	None	Hours or days	Low to high	?
Staphylococcus	Moderate	None	24-48 hours	Incapacitating	?

a. Many sources classify as chemical weapons because toxin are chemical poisons.

Adapted from report of the Secretary General, Department of Political and Security affairs, Chemical and Bacteriological (Biological) Weapons and the Effects of Their Possible Use, New York, United Nations, 1969, pp. 26, 29, 37-52, 116-117; Jane's NBC Protection Equipment, 1991-1992; James Smith, "Biological Warfare Developments," Jane's Intelligence Review, November, 1991, pp. 483-487.

Counterproliferation: The Coalition Effort to Attack Iraqi Biological Weapons

The Coalition attacked two major types of Iraqi biological warfare targets during Desert Storm. The first was infrastructure targets such as the research facilities at Salman Pak and Taji, a suspected production facility near Al-Latifiyah, and two suspected production facilities at near Abu Ghurayb. The second set of targets included possible weapons deployments in the specially designed refrigerated bunkers scattered in various locations in Iraq. Eighteen such bunkers were known before the war, and more were discovered during the campaign.[226]

USCENTCOM issued reports immediately after the war that implied it had destroyed all known key Iraqi biological research and development facilities, and most of

Iraq's refrigerated storage facilities.[227] It is very difficult, however, to be sure of what really happened. Some facilities that the Coalition attacked, like the infant formula plant near Baghdad had dual capability, but it was impossible to determine whether the technology at the plant -- which is useful for developing some forms of dry storable biological weapons -- was ever used for such a purpose. The buildings in the plants (where intelligence had more confidence that Iraq was developing and producing biological weapons) took heavy damage, but a number of senior experts believe that Iraq had removed much of its equipment from these buildings before and during Desert Storm. UN inspectors found more refrigerated facilities, and an analysis of combat damage to some suspected Iraqi biological facilities revealed large secondary explosions, which indicates that they actually held conventional weapons.[228]

The UN did not find conclusive evidence that Iraq was using its research and production capabilities to make biological weapons, although it found some purchases that experts feared might be used to produce storable dry agents and micro-encapsulate biological weapons were not technically suited for this purpose. However, many Iraqi facilities were only inspected by the UN long after the war -- if at all. The equipment to produce biological weapons is easy to disperse, largely dual-use in character, and there are strong indications that Iraq began such a dispersal before the Coalition bombing campaign. The UN never recovered much of the equipment that Iraq stole from biological research facilities in Kuwait, and has been able to keep all of its university research equipment and facilities.

Iraq's Future Biological Weapons Capabilities

Iraqi biological weapons activity has not received the attention given to Iraq's other weapons of mass destruction since the end of the Gulf War. Table 11.7, however, provides a warning that biological weapons can be as effective as small nuclear weapons. One US study of the Gulf War notes that,[229]

> "Experimental data indicate botulinum toxin is about 3 million times more potent than the nerve agent Sarin. A Scud missile warhead filled with botulinum could contaminate an area of 3,700 square kilometers (based on ideal weather conditions and an effective dispersal mechanism), or 16 times greater than the same warhead filled with Sarin. By the time symptoms occur, treatment has little chance of success. Rapid field detection methods for biological warfare agents do not exist. Although Botulinum can debilitate in a few hours and kill in as few as 12, and anthrax takes two to four days to kill, anthrax is much more persistent and can contaminate a much large area using the same delivery means."

Further, the UN has done little to deprive Iraq of any capabilities that it hid before or during the Gulf War. Iraq can rapidly set up covert production centers at university research centers, medical goods and drug production plants, or virtually any other facility where it can maintain a secure biological research and production activity. Robert Gates, Director of Central Intelligence in the Bush Administration, responded to questions about Iraq's biological weapons effort in January, 1992, by stating that "the biological weapons program was also damaged, but critical equipment for it, too, was hidden during the war." Iraq could produce biological agents "in a matter of weeks."[230]

Biological weapons give Iraq an enhanced capability to deter and intimidate the Southern Gulf and the West. Iraq could make overt use of biological weapons in much the same way as it could use chemical weapons. Iraq could also make covert use of such weapons -- which lend themselves to tailored attacks in terms of delay effects and are particularly well suited to unconventional warfare or "terrorism". Biological weapons are Iraq's only near term answer to the effectiveness of the UN inspection and destruction of Iraq's far more visible nuclear, chemical, and missile capabilities. Given Iraq's past history, this makes biological weapons an answer that Iraq is likely to choose.

The effective delivery of highly lethal biological weapons may be beyond Iraq's near-term level of technology, but even anthrax can be extremely deadly, and no one should underestimate the "terror" effect of even a crude biological warhead. Such a weapon might give Iraq major political and strategic advantages in terms of intimidation, and the ability to launch strikes whose political impact was out of all proportion to their direct military value. The use of toxins or persistent biological weapons like anthrax could achieve significant military effects or population damage, and Iraq might just take the risk of using an agent that was a communicable disease, rather than military agents which require direct exposure to the original payload or which are tailored to control their infectiousness.

It is also impossible to dismiss the risk that Iraq will devote sufficient resources using its domestic resources and covert purchases of technology and equipment to develop far more effective biological warheads by the end of the decade. The weaponization and deployment of such warheads involves technical challenges in terms of dry storable agents, microencapsulation, dissemination at critical heights, and predictions of wind and temperature over the target area that may well be beyond Iraq's capability. There are experts that seriously question whether any missile warhead technology would achieve extremely high lethalities -- given the combined challenge of developing a suitable biological weapon and suitable warhead technology. The risk does, however, exist, and it should be noted that it would be easier to weaponize a biological agent for delivery by a relatively slow flying aircraft or cruise missiles than for a ballistic missile.[231]

Lessons For Future Conflicts

It is more difficult to try to project lessons from Iraq's biological capabilities than it is from its chemical capabilities. The effects of Iraq's possible agents range from those discussed earlier for chemical weapons to those of small nuclear weapons. At the same time, biological agents can be used in a host of covert and unconventional ways, and as incapacitating weapons at both the strategic and tactical levels.

As long as the lethality of such agents is restricted, many of the potential lessons are the same as for chemical weapons. Deterrence, countermeasures, and retaliation will, however, be more dependent on the ability to improve intelligence on Iraq's capabilities -- and those of other threat states -- before a war begins. Warning and characterization will be critical for deterrence, treatment, and the use of counterforce, and it will be important to develop a capability to detect and characterize a wide range of agents, and establish methods of tracing the source of weapons that may be used in covert delivery.

There are a number of other modifications that must be made to the lessons drawn for chemical warfare:[232]

- o The US, other Western nations, and any Coalition force engaged in conflict with a chemical power can try to prepare for biological warfare, but the range of possible agents is so broad that protection/treatment may be difficult or impossible, particularly if mixes of different agents are used at the same time. Once again, there is no way to predict whether a nation will engage in chemical warfare, what mix of targets it will choose, and what level of escalation it will be willing to risk.
- o The forces deployed can use some of the gear used in preparing to fight in a chemical environment, and serious consideration should be given to maximize the dual-use aspects of such gear for both chemical and biological warfare. There will, however, be severe limits to what can be done to modify personal protection gear, gear that provides safe work areas, and decontamination gear. Further, none of this gear will be useful without better detection and warning systems, and even with such systems, it may be possible to disseminate agents while forces are unprepared.
- o Rear area facilities can be defended against delivery systems, but it is unclear that they can be protected once an agent is disseminated. Study is needed of the extent to which air bases, key logistics and reception sites, and other areas involving heavy troop concentrations can be protected or kept functional.
- o Power projection forces must be even more prepared for rapid dispersal, mobile warfare and operations in depth to reduce vulnerability to biological warfare.

- o Active air and missile defenses will generally offer a higher probability of protection -- if conventional delivery systems are used -- than trying to protect the facility with passive defenses.
- o A deterrent and retaliatory offensive capability to reduce the risk of use and exact penalties for such use will generally be more effective than defense. It is unclear, however, that conventional strike options can really be lethal enough to deter use or successful intimidation.
- o A strong regional conventional retaliatory capability may increase the willingness of friendly states to resist intimidation and support power projection efforts, but much will depend on the lethality of the threat and the credibility of use. Overt or proven biological warfare capabilities are likely to increase the risk that friendly or moderate states will develop their own weapons of mass destruction, and it is not clear what the US or the West can offer as an alternative.
- o Counterproliferation is very unlikely to deprive a nation of biological strike options in the near future. Improved strike plans for key threat nations, and improved sensors and intelligence collection methods, are not likely to prevent threat states from developing launch under attack or covert delivery capabilities and improved methods of dispersal. Nevertheless, counterproliferation capabilities should be improved at least to the point where a potential user faces some risk of losing a substantial amount of its biological capability.
- o Controls on technology transfer and feedstocks, and attempts to enforce arms control agreements like the Biological Weapons Convention may have a limited effect. They are, however, likely to be far less successful than similar efforts to control or limit chemical and nuclear proliferation.

The past inattention to biological weapons and the lack of any recent successful use of such weapons, may reduce the level of proliferation in this area and the credibility of biological weapons in intimidation and war fighting. It may, on the other hand, inspire a nation to use such weapons to demonstrate credibility, and Third World states are likely to greatly improve their understanding of such weapons over the next few years. If biological weapons are deployed with near nuclear lethality, the only real method of countering such capabilities may be the tacit or overt threat of using nuclear weapons. This could confront the US and other nuclear weapons states with very hard choices about providing some form of extended deterrence to friendly states in the Third World.

It is clear from the preceding discussion that biological weapons also present exceptional problems for counter proliferation. The Gulf War has shown that attempts to use surgical bombing to destroy the ability to manufacture and deliver weapons of mass destruction may often be an unworkable approach to counterproliferation. It indicates that suspected facilities and facilities with significant dual capability must be attacked even at the cost of considerable collateral damage and increased civil casualties. It also indicate that such facilities must be hit hard indeed to have a major effect. Attacks on facilities like the "baby milk formula plant" near Baghdad may never be popular with the media or be politically correct, but it will take a total revolution in intelligence to make them unnecessary if counterproliferation is to be effective.[233]

Table 11.7

The Comparative Effects of Biological, Chemical, and Nuclear Weapons Delivered Against a Typical Urban Target in the Middle East

Using missile warheads: Assumes one Scud sized warhead with a maximum payload of 1,000 kilograms. The study assumes that the biological agent would not make maximum use of this payload capability because this is inefficient. It is unclear this is realistic.

	Area Covered in Square Kilometers	Deaths Assuming 3,000-10,000 people Per Square Kilometer
Chemical: 300 kilograms of Sarin nerve gas with a density of 70 milligrams per cubic meter	0.22	60-200
Biological 30 kilograms of Anthrax spores with a density of 0.1 milligram per cubic meter	10	30,000-100,000
Nuclear:		
One 12.5 kiloton nuclear device achieving 5 pounds per cubic inch of over-pressure	7.8	23,000-80,000
One 1 megaton hydrogen bomb	190	570,000-1,900,000

Using one aircraft delivering 1,000 kilograms of Sarin nerve gas or 100 kilograms of anthrax spores: Assumes the aircraft flies in a straight line over the target at optimal altitude and dispensing the agent as an aerosol. The study assumes that the biological agent would not make maximum use of this payload capability because this is inefficient. It is unclear this is realistic.

	Area Covered in Square Kilometers	Deaths Assuming 3,000-10,000 people Per Square Kilometer
Clear sunny day, light breeze		

Sarin Nerve Gas	0.74	300-700
Anthrax Spores	46	130,000-460,000
Overcast day or night, moderate wind		
Sarin Nerve Gas	0.8	400-800
Anthrax Spores	140	420,000-1,400,000
Clear calm night		
Sarin Nerve Gas	7.8	3,000-8,000
Anthrax Spores	300	1,000,000-3,000,000

Source: Adapted by the author from Office of Technology Assessment, Proliferation of Weapons of Mass Destruction: Assessing the Risks, US Congress OTA-ISC-559, Washington, August, 1993, pp. 53-54. Note that the OTA data do not examine the future possibility of genetic weapons or of advanced chemical weapons that may be far more lethal than today's nerve gases.

Iraq's Nuclear Program and the Risk of Nuclear And Conflict

Of all the might have beens in the Gulf War, the most dangerous to the Coalition is what might have happened if Iraq had waited to acquire nuclear weapons before it seized Kuwait. Any judgment about whether the Southern Gulf states, the US, and the Coalition would have had to resolve to liberate Kuwait under such circumstances must be speculative, but the answer would probably have been "no". The world might still have been willing to try armed sanctions, but it seems doubtful that it would have been willing to risk nuclear war by liberating Kuwait.

This is an important point to bear in mind in examining the lessons of the Gulf War. Iraq lacked the chemical capabilities to threaten its neighbors or Western power projection forces with true mass destruction. It had the potential for acquiring biological weapons as lethal as small nuclear weapons, but it is not clear that such weapons will ever have anything approaching the deterrent and intimidating impact of nuclear weapons until they are actually used.

In contrast, nuclear weapons could have destroyed any military area target in the region, and threatened most nations in the region with the destruction of their political and economic structure. Even Iran and Turkey would suffer immense damage from a single strike on their largest population center, and nations like Israel, Saudi Arabia, and the smaller Gulf states are virtually "one bomb" countries. A strike on Riyadh, Tel Aviv, or the capital city of any small Gulf state would be so devastating that even if the nation could recover it would be so different from the state that existed before the war that much of its political and economic structure would be unrecognizable.

Iraqi Nuclear Capabilities at the Time of the Gulf War

The intelligence and targeting lessons of the Gulf War regarding Iraq's nuclear capabilities have already been discussed in Chapter Five. The US failed to properly characterize the Iraqi nuclear effort before and during the war. It firmly identified only two out of 21 Iraqi nuclear facilities before the war, and identified two more facilities as suspect. It never fully identified the actual function of any facility, and it identified the site at Al-Athir so late in the war that this became the last target of the F-117.[234]

By the time the war took place, the US had expanded its list to eight targets, but it failed to realistically assess battle damage to these targets. The US was forced to strike them again in the final days of the war, but never had the opportunity to reexamine battle damage and strike again. UN inspectors found after the war that air strikes did major damage to the Baghdad Nuclear Research Center and to Iraq's two known reactors, but it also found that many of the Coalition air strikes were far less effective than was originally estimated.[235]

Some of these problems were a result of the sheer scale of the Iraqi effort. US experts estimate that Iraq spent up to $10 billion during the 1980s to acquire Calutron and centrifuge enrichment facilities, to develop other methods of enrichment, and to acquire the technology and equipment to use fissile material in a nuclear weapon.[236] This involved what the UN Special Commission (UNSCOM) later called, "a grandiose and over-designed program."[237] By this time, the Iraqi program was called Petrochemical 3 or PC-3.

At the time the Gulf War began, Iraq had some 20,000 Iraqi workers involved in its nuclear weapons effort. There were eight dedicated nuclear weapons development sites, with dozens of major processing buildings worth several billion dollars. A wide range of facilities that the UN had found had some connection to the Iraqi nuclear weapons effort are listed in Table 11.8.[238]

Table 11.8

Key Iraqi Nuclear Weapons Facilities: Part One

o *Abu Ghraib:* Military base and fuel-rod storage.

o *Abu Sukhayr:* Exploratory mine located about 25 kilometers south-west of Najar. Production from September, 1988 to end of 1990, when was flooded. uranium in ore ranged from 80 to 800 ppm.

o *Ahashat:* Phosphate and open faced uranium mine. uranium extraction.

o *Amil:* Liquid nitrogen for Calutron program.

o *Amir:* Calutron component manufacturing: Magnet cores, return irons, ion sources, collector parts.

o *Ameen:* Calutron component manufacturing - prototype components.

o *Atheer:* Some 350,000 square feet of lab space that was largely untouched by the war. Nuclear weapons design and testing of high explosives. Hydrodynamic studies. Large cold isostatic press for shaping explosive charges by Asea Brown Boveri. High temperature vacuum induction furnaces by Arthur Pfeiffer Vacuum Technik GmbH. Planned casting and machining of fissile material, machining of uranium plates, and assembly of explosive structure and core of nuclear weapons. Plasma coating molds and mold fabrication. Design of regular implosion type nuclear weapon.[239]

o *Badr:* Centrifuge component manufacturing. Civil contracting for Al Furat project.

o *Daura (SEHEE):* Calutron component manufacturing - Vacuum chamber parts. Civil contracting for Al Furat project.

o *Dijila:* Electronics plant supporting general fabrication activities for the IAEC. No specialized weapons production equipment.

o *Fao:* Contracting for Al Furat project.

o *Falluja:* Military base and equipment storage.

o *Furat (Farat or Pharat):* Centrifuge research. Two centrifuge manufacturing sites. Maraging centrifuge facility. Had begun with a Beams type and was capable of making the more advanced Zippe type by mid-1987. Iraqi initially claimed they were capable of producing up to 200 centrifuges a year. The manufacturing equipment intended for installation indicates that the true figure was 2,000.

o *IRT-5000:* Po-210 production.

o *Jazirah:* uranium processing; UCl_4 production. Calutron and centrifuge production.

o *Al Hadre:* High Explosives research and hydrodynamic studies.

o *Hatteen:* High explosives research; main explosive structure research.

o *Musayyib:* Materials research and high explosive test site. Test range for shaped charges. Power plant. Nuclear weapons laboratories.

o *Mosel:* UCl_4 production.

o *Nafad:* Calutron component storage.

Table 11.8

Key Iraqi Nuclear Weapons Facilities: Part Two

o *Nasser Works:* Centrifuge component manufacturing and machining.

o *Al Qa Qaa:* Development of non-nuclear components and explosives for nuclear weapons. HMX production and casting for weapon, pressing and machining, main explosive structure of weapon, explosive lens building, and lens assembly. Detonator research. Exploding bridge wire detonators. Research facility for Ministry of Industry and Military Industrialization.

o *Qa'im:* Superphosphated fertilizer plant, uranium extraction plant and yellow cake production. Heavily damaged during the war.

o *Al Radwan:* Centrifuge component manufacturing: Magnet cores, return irons, ion sources, collector parts.

o *Al Rashidiya:* Maraging centrifuge facility.

o *Ar Rabiyah:* Manufacturing workshops for producing metal and ceramic components for the IAEC. Its main function w as support of the Calutron program. It had high quality, although not specialized, machine tool capabilities. It was badly damaged by a cruise missile attack in early 1993.

o *Saddam Works:* Calutron component manufacturing and centrifuge machining.

o *Salladine:* Calutron component manufacturing -- electrical control panels.

o *Ash Shakyli:* Warehouse storing centrifuge components.

o *Ash Sharqat:* About 250 kilometers north of Baghdad. Worked started in 1988. Three groups of facilities. uranium enrichment for Calutron. An Iraqi duplicate of Tarmiyah, with 600mm and 1,200mm Calutrons, was under construction but not yet operational.

o *Suwayrah:* Nuclear equipment.

o *Tarmiyah:* Calutron research. Main production site for uranium enrichment. 8 working 1,200mm Calutrons. 17 1,200mm improved Calutrons being installed. Building for 20 600mm Calutrons under construction. Capacity of 90 600mm and 1,200mm Calutrons. This could have produced 15 kilograms of 93% enriched uranium per year, and more of less enriched uranium. (This complex was built by the Yugoslav Federal Directorate of Supply and Procurement and equipped by the Yugoslav firm of EMO electrical Engineering)).[240] Also, computer facility. Largely destroyed during the war.

o *Technical University of Baghdad:* Streak video cameras and related equipment suitable for weaponization work by Hamamatsu.[241]

o *Tikrit:* Storage of yellow cake.

o *Tuwaitha:* A major research and production center. Site of damaged Tamuz 1 and Tamuz 2 reactors, and IRT-5000 reactor (heavily damaged in war). Nuclear physics labs. Main computer facility with IBM-370 main frame and many IBM PS/2s. uranium research and development. UCl_4 and UF_6 production. Calutron and centrifuge tests, plutonium separation, and chemical separation. 5 working Calutrons. Gaseous diffusion research. Po-210 extraction and neutron initiator research and design. UF_4 production. Metal reduction, casting, and machining. Research on implosion nuclear weapon. Firing system research and design.

o *Zaafarniyah:* Al Dijla and Al-Rabee sites fabricated Calutron components.

o *Walid:* Centrifuge factory.

Most of these facilities were not declared to the IAEA, nor subject to its inspection, and many only became known after UN inspections following the Gulf War. While Iraq relied on dispersal and secrecy to protect some of these facilities, it also established surface-to-air missile defenses at major facilities like Tuwaitha.[242] These defenses were combined with hardened shelters at locations like Tuwaitha and Al Atheer, and Iraq had at least one underground facility in a mountain near Irbil.[243]

In spite of all its efforts, Iraq only had a total of 27.5 pounds (11.3 kilograms) of French-supplied 93% enriched uranium -- which was left over from the Tamuz 1 reactor destroyed by Israel -- and 22.3 kilograms of Russian-supplied uranium with levels of enrichment varying from 36% to 80% for its Russian-supplied IRT-5000 research reactor by the late 1980s.[244] Only the French material could be used in a bomb. Using this limited amount of material to build even a single weapon also required the use of very complex implosion technology, since such material cannot be used in the simpler weapon's designs made possible by using plutonium or mixes of uranium and plutonium. Iraq would also have had no surplus material to test its weapon design.[245]

After the Gulf War, the UN Special Commission (UNSCOM) found that Iraq had managed to extract a little over five grams of weapons grade plutonium. Later examination of the source of Iraq's plutonium indicated that its plutonium came from two sources. First, 2.26 grams of plutonium had been separated at a small laboratory at the Tuwaitha Nuclear Research Center. This had evidently been separated between 1982 and 1988 after the IAEA exempted five fuel elements for the Soviet IRT-5000 research reactor from inspection which contained 10% enriched uranium. Such an IAEA exemption is normal for small amounts of material used for research purposes.

The second batch of 3 grams was also separated at Tuwaitha. This time, however, Iraq used natural uranium that it had separated at Al Qa'im in northern Iraq. Iran inserted about 11 kilograms of this processed uranium into its research reactor. Iraq had sent another 8 kilograms to Tuwaitha by the start of the war, but none of this had not been processed by the time the UN inspected the facility.

This plutonium enrichment activity demonstrates Iraq's interest in nuclear weapons, but it must be kept in perspective. Iraq never pursued an intensive effort to develop large amounts of plutonium. In fact, if Iraq had used its facilities in this way, 24 hours a day for a year, it would still only have obtained 100 grams of plutonium. It takes approximately 8 to 10 kilograms of plutonium to make a nuclear weapon, and there is no evidence that Iraq had a secret reactor or large scale facility for plutonium production. This is, however, a possibility and some UN inspectors and outside experts feel that Iraq may still have a facility that the UN has not found.[246]

Iraq actively sought centrifuge technology from the US, Europe, and the People's Republic of China, which led to a number of incidents over attempts to smuggle equipment to Iraq. The US blocked an attempt to acquire the specialized pumps needed for cascade facilities in February, 1989, and other Iraqi attempts to smuggle centrifuge technology from the US to Iraq in 1988 and 1989 were blocked by US officials. Nevertheless, Iraq made progress towards creating a centrifuge enrichment capability, and meeting a long-term goal of 10,000 operating centrifuges.[247] Iraq had a Beams-type centrifuge by mid-1987, and a more advanced Zippe-type by mid-1988. The UN Special Commission (UNSCOM) found that Iraq purchased centrifuge technology and equipment from thirteen different German companies, and found a plant at Al Furat that had escaped the Coalition bombing that Iraq had designed to produce 200 centrifuges a year.[248]

Iraq used the designs for an early URENCO G1 centrifuge -- possibly obtained through Interatom, a wholly owned subsidiary of Siemens. It also had some of the designs for the URENCO G2 and G3 centrifuges, and a 1988 centrifuge design by MAN Technologies GmbH of Munich.[249] It acquired the specialized drill presses, and rolling machines or lathes, for manufacturing enrichment centrifuges during 1987-1988.[250] Iraq acquired machinery to manufacture end caps and flow-forming machines to make the thin and precisely machined rotors for centrifuges out of maraging-steel tubes. It acquired 240,000 ferrite magnet spacers, 300 tons of special aluminum alloy for vacuum housings, and 84 tons of special aluminum alloy for molecular pumps. In 1989, Iraq acquired at least 100 tons of maraging steel-350, a high nickel content steel whose primary use is in uranium centrifuges, although not enough was found to provide for a major centrifuge manufacturing effort, and some experts feel that Iraq's rotors were still of low grade at the time of UN inspection.[251]

Iraq obtained the samarium cobalt magnets used to hold the centrifuge in place during high speed rotation. It acquired the specialized vacuum pumps used to circulate uranium hexafluoride gas through gas centrifuges.[252] Iraq set up a hydrogen fluoride plant at Al-Qa'im, in a facility plant used for phosphate production. Hydrogen fluoride is needed to produce uranium fluoride gas.[253] Iraq made enough progress to set up a maraging centrifuge facility at Al-Farat, and another at Al-Rashidiya. The German investigation of the actions of H&H and technicians associated with MAN, indicated that this manufacturer played a major role in setting up a nuclear materials research and centrifuge manufacturing plant at Tuwaitha, and that research and development work on centrifuges was taking place at the Sa'ad 16 center near Mosul.[254]

Iraq planned to have a 100-machine cascade in operation by 1993 and a 500-machine cascade in operation by 1996. If all its plans had succeeded, it might have had

2,000 machines on line by the late 1990. Under optimal conditions, a line or cascade of 2,000 centrifuges can produce 40 to 50 pounds of highly enriched uranium a year, or about enough to produce one bomb.

The centrifuge, however, is a difficult path to enrichment.[255] The UN Special Commission (UNSCOM) found serious problems in the quality of Iraq's centrifuge technology and production equipment, and stated that, "...Procurement of tons of specialty metals and components, enough to build thousands of machines, was discovered....Two centrifuge prototypes were tested with some success in test bed experiments....The Iraqi program was in a very early stage using clandestinely obtained European designs and illicitly obtained materials to build a few research machines." [256]

To put the Iraqi effort in perspective, Pakistan seems to have taken nine years to build a centrifuge enrichment facility, and still only seems to have about 1,000 out of 14,000 centrifuges running at its plant at any one time. Brazil took ten years to get a small plant running at Aramar, with only 50-75 centrifuges, although it was well on its way to operating a full scale 2,000-3,000 centrifuge plant by 1990.[257]

As for other methods of enrichment, Iraq showed no interest in laser isotope separation, limited interest in chemical and jet nozzle separation, and a major interest in Calutron enrichment. Iraq tried both Japanese and French techniques for chemical separation which rely on catalysts to speed up the exchanges between U-235 and U-238. It abandoned the Japanese technique, but continued working on the French technique in order to obtain a relatively cheap and efficient method of low level enrichment. It only seems to have made limited progress in jet nozzle technology, and abandoned it.[258]

Iraq's efforts to use Calutrons were only discovered after the Gulf War. The Iraqi effort was so covert that it led a number of experts to speculate that Iraq had taken advantage of deception techniques to hide its activities from US satellites that it obtained from the Soviets after the Israeli attack on Osirak, and from studying US satellite photos of Iran that the US had supplied to Iraq during the Iran-Iraq War.[259]

Iraq's major Calutron facilities have been listed earlier. The UN has not fully disclosed what it has discovered about the effectiveness and technical details of the Iraqi Calutron effort or the names of its foreign suppliers. It is clear, however, that Iraq set up electro-magnetic isotope separation (EMIS) facilities at Ad Dijjla, Tarmiya, Ar-Rabiyah, and Al-Hamath and in the Zaafarniya section of Baghdad.[260] After the Gulf War, the UN Special Commission (UNSCOM) found that these involved the production of massive equipment assemblies that included at least thirty 12 foot disks weighing 60 tons.[261]

While several Calutrons were built, their importance has been exaggerated in the press. The UN Special Commission (UNSCOM) stated in June, 1993, that "The program was facing serious difficulties in start up and implementation due to a lack of technical depth among Iraqi technicians. It would have been several years before it produced enough uranium for military purposes." [262]

Iraqi plans seem to have called for 70 alpha and 20 beta Calutrons to have become operational during August, 1989-December, 1992, but only eight alpha Calutrons were installed by the end of 1989. Iraq was just beginning to install another 17 alpha machines when the Coalition attacked in 1990, and it is unlikely that Iraq could have had enough machines operational to produce one nuclear weapon a year before 1994 at the earliest. The machines that were installed do not appear to have been functioning with high reliability at a significant scale, or to have had the throughput required to support a major weapons effort. They could, however, have been more effective as a way of preparing enrichment material for further enrichment by centrifuges. The UN Special Commission (UNSCOM) noted that the Calutrons could be used for high capacity-low enrichment operation and the centrifuges for low capacity-high enrichment.[263]

Although the UN eventually traced about 500 tons of natural uranium that moved into the Iraqi processing system, Iraq seems to have produced only grams of enriched uranium and milligrams of 40%-45% enriched uranium in the facility at Tuwaitha, which was constructed in 1985-1986. Iraq began operating the Calutrons at Tarmiya in February, 1990, and produced a total of 500 grams of 4% enriched uranium with some at a high of 10%. However, the facility at Tarmiya was still in the test bed stage when the war ended, and each Calutron had four ion sources and a design beam current of 145 milliamps of uranium ions. Iraq was experiencing problems in keeping all the ion sources operating at once and maintaining stable beams, but had evidently solved most of its the development problems except the ion source.[264]

Iraq was installing a circular system, or "racetrack," of 17 Calutrons to produce low enriched uranium when the war began -- with the goal of installing up to 70 low enrichment units and 20 high enrichment units. None of the high enrichment Calutrons were installed or operating, but UN officials speculated that they might eventually have produced 12-90 kilograms a year of uranium with an enrichment level of at least 90%. Such production, however, required all four beams in each machine to operate at 145 milliamps and all machines to operate an average of 55% of the time. An output of 8-9 kilograms would have been more likely.

As these enrichment efforts moved forward, Iraq also steadily expanded what Iraq later admitted was its nuclear weapons design facility at Al Atheer.[265] Al Atheer was involved in research relating to the production of plutonium, polonium-210, natural uranium metal, enriched uranium metal and yellow cerium sulfide.[266] It worked on detonation and neutronic tests, nuclear initiation, and used flash X-Rays to see what happened during nuclear weapons detonation tests. It also worked on firing systems, control, and guidance. Projects included explosive lens testing and analysis, natural uranium reflector design, polonium 210/beryllium neutron initiators, hardened iron tampers, synchronization and timing systems, pulse power equipment, charging power equipment, junction switches, capacitors, and related measurements.[267]

The UN found some 40,000 pages of documents relating to the Iraqi nuclear weapons design effort, and sophisticated one and two-dimensional computer codes tailored to nuclear weapons design.[268] Work by the UN inspection teams found that Iraq had concluded that gun type devices need more material, although they were simpler and had fewer calculation requirements. Iraq concentrated on an intermediary implosion type device, and to focus on a yield of 20 kilotons -- similar to the nominal yield of the weapon dropped on Nagasaki. Iraq had performed 20 detonation experiments relating to such designs by May 31, 1990 -- the last date referred to in UN-held Iraqi reports.[269] It is important to note that no records have yet been discovered for the period after May, 1990, and that no record exists of design activity using plutonium weapons although Iraq had plutonium.

The Iraqi weapons design that the UN found could have produced a weapon weighing about 1,000 kilograms (one metric ton).[270] This mass, and the basic weapons design, was consistent with deployment as the warhead of a Scud missile. The actual weapon was similar in some ways to the US "Trinity" weapon that the US set off in New Mexico on July 16, 1945. It consisted of a "soccer ball" shaped set of explosive lenses surrounding a pit of fissile material enclosed in a reflector -- made out of depleted uranium or beryllium. The pit was a solid sphere of uranium, with sufficient highly enriched uranium to approach one critical mass. Using such a large mass of uranium greatly increases the probability that a nuclear device will produce a significant yield even if the high explosive is relatively unsophisticated, and reduces the amount of explosive needed to compress the enriched material to supercriticality.

At the time the Gulf War began, Iraq had purchased components for the high melting point explosive (HMX) and rapid detonation explosive (RDX) needed to compress fissile material into a critical mass.[271] The Iraqis had ample supplies of Baratol and HDX high explosives, and understood the use of aluminum "flying plates" to increase the pressure wave. Although the Iraqis were experimenting with single high explosive lenses to test their ability to produce a large enough planar shock wave to set off the critical mass, there is some question as to whether they could have properly shaped the shock front around such a mass.

Iraq planned to use a hardened iron tamper, and a Polonium-210 metal/beryllium neutron initiator. The neutron initiator is the device needed to supply a burst of high energy neutrons at the correct instant necessary to start the chain reaction and keep it from damping out. Iraq obtained its polonium 210 from Bismuth, and completed 20 tests of a polonium-beryllium neutron initiator.[272] Iraq had designed and successfully tested its own neutron initiator using explosive lenses and dummy core material just before the Gulf War began. Iraq had also developed and tested high energy pulse junction switches, which can act as a somewhat inferior substitute for krytrons.

The krytrons would have been superior, which helps explain Iraq's effort to smuggle high speed, high voltage, capacitors from the US in March, 1990.[273] It is not absolutely certain that Iraq wanted the capacitors for nuclear weapons. They have a number of other potential military applications, such as triggering the high explosive charges in a gas cannon, and the capacitors are co-axial, high voltage, low inductance devices that have exceptional resistance to humidity, vibration, and shock. Nevertheless, the krytrons involved were identical to the devices used in US nuclear weapons and they are perfectly suited to deliver the instant burst of electricity, or triggering charge, necessary to detonate all of the high explosive hemispheres surrounding nuclear material in order to ensure that it is compressed into critical mass with optimum efficiency.[274] Without access to such technology, Iraq still faced problems in miniaturizing its nuclear devices, mating them to missile warheads, making effective use of its limited fissile material, and enhancing the yields it could obtain. It also risked producing weapons sensitive to shock and accidents.

Because Iraq calculated that minor shifts in design could produce a yield as low as one kiloton, and lacked predetermined values for several critical calculations, it was using one dimensional integrated codes for much of its design work. The bulk of this calculation work seems to have been done at Tuwaitha, using an IBM 370 mainframe and smaller IBM PS/2 computers, although the hydrostatic calculations were performed on an NEC mainframe computer. The UN found that Iraq had conducted such computation to support weaponization studies, hydrodynamic calculations, exploding wire studies, initial neutron initiator studies, energy source studies, neptunium and U-233 experiments, and lithium-6 experiments[275]

Iraq had obtained x-ray crystal measurement, mass spectrometers, and beryllium. It bought $96 million worth of computers from the US between 1984 and 1990, about $26 million of which went to Iraqi military facilities, and large amounts of optical fiber.[276] Further, the UN Special Commission (UNSCOM) reported that Iraq was producing, or had obtained, up to 220 pounds of Lithium-6 a year. Lithium-6 can be used both in thermonuclear weapons, and to enhance the yield of fission weapons. The UN concluded from Iraqi records that Iraq might have been using Lithium to work on a boosted weapon.[277]

The exact level of Iraq's overall success in warhead design at the time the Gulf War began is still a matter of some debate.[278] The report of IAEA Director Hans Blix to the UN Security Council on the results of the sixth IAEA inspection of Iraq indicates that Iraq had made substantial progress:[279]

> "The key result of the sixth inspection is the uncovering of documents that show conclusively that Iraq was very well advanced in a program to develop an implosion-type nuclear weapon and that links existed to a surface-to-surface missile project. In deed, so advanced has this program been deemed to be that the time needed to reach bomb-making capacity seems to have been determined by the time necessary for the enrichment facilities, rather than the weapons design activities.
>
> "...The sixth report also uncovered evidence of broad-based Iraqi international procurement efforts in violation of laws of States from which the export originated. However, much, if not most of the procurement of which evidence will be available, will be found to pertain to equipment and material not subject to export controls elsewhere." [280]

What is not clear is whether Iraq could have refined its design to the point where it could actually have used it to produce a weapon until 1991-1992, or then deployed a functioning weapon without several years of additional development and research work and testing.[281] Iraq might not have found predictability of yield to be critical. Even a partial success, or "fizzle", that only produced a 5-6 kiloton yield is still an extremely effectively weapon. An outright failure to explode, however, could cost Iraq roughly $100 to $200 million per weapon until it developed a major fissile material production capability, and represent a significant portion of Iraq's total stockpile.

Iraq faced the risk that a nuclear weapon susceptible to shock, accidental triggering, or partial detonation from causes ranging from static electricity to misuse of safety interlocks could do devastating damage to Iraqi territory. There are some indications that the bomb that Iraq designed "crammed" so much high explosive into a narrow area that it was highly sensitive to shock and accidental detonation.[282]

Iraq also faced the challenge of mating a nuclear weapon to a delivery system. It had to develop the technology necessary to carry bombs on airplanes in ways that ensured safe and proper release, to develop accurate delivery methods, and to find ways to fuse the bombs to provide reliable control over the height of burst.[283] It needed to develop missiles that were so reliable that there was almost a zero chance of the loss of one of Iraq's limited number of warheads. It also needed to improve its warhead design. Iraq's warhead technology was limited and unreliable at the time of the Gulf War, and presented a risk of missile system failure, reduced accuracy, and catastrophic warhead failure.

Finally, Iraq faced the problem of nuclear weapons security. The seizure of a nuclear weapon could give any political faction a dominant role in a coup attempt or struggle for power. In the case of a revolution, or ideological struggle, it could easily threaten the existence of the regime or lead to the use of a weapon that could trigger a major war. However, creating effective security systems and devices is not easy. Security devices that are internal in the weapon are probably the only way of ensuring a reasonable degree of central government control, but effective designs must be built into every aspect of the weapons design and can interfere with weapons function. Less stringent protection systems can be bypassed in relatively short periods of time, or by disassembling one weapon to learn how to bypass the security systems on the others.

Counterproliferation: The Coalition Effort to Destroy Iraqi Nuclear Weapons Production Capability

As has been discussed in Chapter Five, the Coalition effort to attack Iraq's nuclear facilities was a major failure. At the start of Desert Storm, US intelligence had only identified two Iraqi nuclear targets as certain, and two as possible. It eventually identified four more targets, but many of strikes on the eight Iraqi facilities that had been identified by the end of the war were ineffective, and battle damage assessment was a failure. Further, the UN later found twenty-one Iraqi nuclear weapons facilities that met the targeting criteria used during Desert Storm.

One of the lessons that emerges from this experience is that intelligence cannot locate every secret facility in an authoritarian society, or even be sure that it can characterize the scale of the nuclear or proliferation effort involved. Western intelligence failed to understand every aspect of the Iraqi nuclear program. As the USAF Gulf War Air Power survey notes,[284]

> "...other than the uranium mine at Al Qaim, the only known nuclear target on the Black Hole's 16 January 1991 target list was the large complex at Al-Tuwaitha. By the end of the war, the number of nuclear targets had grown to eight, and bomb damage assessment in Washington suggested that a fairly complete job had been done against them. As of 27/28 February 1991, the DIA was holding five of these targets destroyed, two damaged, and only one operational. However, just two days after the war ended, the Black Hole was given a list of eight 'nuclear' targets to hit in the event that bombing was resumed. While several in this list consisted of structures at known locations like Al-Tuwaitha that had not been sufficiently damaged, others involved locations such as Ash

> Sharqat whose involvement in the Iraqi nuclear program had not previously emerged. And, by the end of October 1991, UN inspection teams had uncovered a total of twenty-one different facilities that were involved in the Iraqi nuclear program."

It is unclear that any intelligence effort can ever be certain of characterizing the full range of proliferation activities in a closed authoritarian society. At the same time, the Gulf War is a lesson in the fact that counterproliferation requires both a major dedicated intelligence effort and a willingness to examine all of the possible paths to proliferation. The worst possible approach to counterproliferation is to repeat the mistakes before and during Gulf War. Here again, the Gulf War Air Power survey is a warning,[285]

> "The Iraq nuclear program's redundancy, advanced status on the eve of war, and elusiveness, in conjunction with the extraordinary measures the Iraqis took immediately after Desert Storm to conceal its extent by destroying certain facilities, all argue that the air campaign no more than "inconvenienced" Iraqi plans to field nuclear weapons. When all was said and done, too many elements of the Iraqi nuclear program were unidentified during Desert Storm, incompletely understood, or else moved out from under the Coalition bombing soon after the air campaign began....In hindsight, this conclusion is suggestive of an intelligence failure. Planners cannot target things whose existence is unknown to them...the first order questions about the extent to which active deception and concealment measures by the Iraqis might be able to complicate Coalition targeting, or to reduce substantially the effectiveness of even precision bombing, do not appear to have been asked, much less vigorously pursued. Thus, the intelligence failure in this particular area was also accompanied by a conceptual failure to think through the range of feasible countermeasures and responses the Iraqis could take."

Another lesson, discussed for other targets in Chapter Seven, is that the continuing exaggeration of the impact of strategic bombing that has characterized thinking and action regarding airpower since World War I is not a meaningful approach to war fighting. Strategic bombing can only be effective if the function and importance of the target is fully understood and the assessment of damage is realistic. Once again, the Gulf War Air Power survey notes,[286]

> "If anything, the gap between weapons impacting known aim points and the achievement of operational strategic effectiveness against target systems was even larger in the case of the Iraqi nuclear program (than in the case of other strategic bombing targets)....we know now in retrospect that the Iraqis' program

to amass enough enriched uranium to begin producing atomic bombs was more extensive, more redundant, further along, and considerably less vulnerable to air attack that was realized during Desert Storm. Further, Iraqi willingness, once the war began, to take such unorthodox measures as removing nuclear fuel or critical machinery to fields or other areas adjacent to known nuclear installations like Tuwaitha quickly made Iraq's nuclear facilities less vulnerable to bombing, no matter how accurate, than it had been during Desert Shield. In this sense, elements of the Iraqi nuclear program were transformed into targets that could be and were, relocatable."

Like the Coalition's failures to attack the Scuds, chemical weapons, and biological weapons, the failure to successfully characterize and attack Iraq's nuclear weapons facilities is a warnings about the potential effectiveness of counterproliferation.

Iraq's Future Nuclear Weapons Capabilities

The UN has made a major effort to deprive Iraq of its weapons of mass destruction since the Gulf War, and has played an important role in exposing and reducing Iraq's capabilities. Under the terms of the cease-fire in the Gulf War, Iraq committed itself to allowing UN inspected destruction of its biological, chemical, and nuclear weapons facilities, and Long-range missiles. On April 3, 1991, the UN Security Council passed Resolution 687, which led to the creation of a special commission to prepare a plan for the destruction and removal of Iraq's biological, chemical, and nuclear weapons materials and facilities. This UN Special Commission (UNSCOM) authorized the International Atomic Energy Agency (IAEA) to carry out part of this task and created a force of UN inspectors to perform to rest.

A total of 53 UNSCOM and IAEA inspections were completed as a result of this resolution between the first inspections in June, 1991, and March 1993 -- the period in which the UN was most likely to make significant discoveries. These included 18 nuclear inspections, 15 chemical inspections, three biological inspections, 16 ballistic missile inspections, five special missions, and one monitoring team visit.[287] Most of these inspections encountered significant Iraqi resistance and lies, but the UN effort has probably been relatively successful in dealing with large Iraqi nuclear facilities and in planning a continuing monitoring effort.[288] It was often difficult or impossible for Iraq to conceal or disperse major equipment. Iraq has, however, succeeded in hiding much of its technical data, the names of many of its suppliers, and much of its smaller equipment. Iraq also retains its nuclear weapons designs and technological experience.

Like Iraq's missiles and chemical and biological warfare capabilities, the game of nuclear hide and seek between the UN and Iraq is likely go on for years.[289] Even if Iraq does allow the UN to continue to monitor Iraq's activities, this is unlikely to solve the problem. Iraq will retain the technology base that it acquired before the Gulf War, and can go on with a great deal of research and engineering activity with little fear of a challenge from the UN. It also has developed a long list of secret suppliers in the past and it is far from clear that it cannot create an equally long list of suppliers in the future.[290]

Lessons For Future Conflicts

The risks that nuclear proliferation poses are so high that they almost inevitably have to be dealt with on a case by case basis, and by developing solutions tailored to specific national and regional delegation. Once again, some "lessons" can be drawn from speculating on how a nuclear armed Iraq might have changed the outcome of the Gulf War:

- The Gulf War is likely to encourage rogue or aggressive states to proliferate. It demonstrates that the West's advantages in conventional warfare cannot be offset with mass, but that even long range delivery systems without chemical, biological, and nuclear weapons can have a major political and strategic impact. Whether nuclear weapons really are or are not an "equalizer" in dealing with regional powers, the West, and the UN may be uncertain, but this is an uncertainty that many aggressor states may try to exploit.
- The Gulf War demonstrates the need to seek to limit and prevent proliferation through arms control and controls on technology transfer. Suitable measures include strengthening the NPT, and international inspection and verification measures in the way suggested by Hans Blix, the Director of the IAEA, and a number of others.[291] Arms control and inspection, however, are unlikely to have complete success in a world where there is a growing surplus of plutonium, the feeling among some nations that countries have a right to proliferate, and where the cost and difficulty of using technologies like the centrifuge and plutonium processing to produce to fissile material is dropping.[292]
- There is a need to examine what can be done in terms of counter-proliferation, both in terms of striking at weapons and delivery capabilities and providing active and passive defense. It is unlikely that any near or mid term steps can provide a high degree of security against a power like Iraq, but they may well enhance deterrence and reassure friendly regional powers.
- The US, other Western nations, and any UN force engaged in conflict with a chemical power can try to prepare for nuclear warfare, but such conflict is so lethal, that such efforts may have limited success. The experience of NATO regarding nuclear sheltering and decontamination efforts is scarcely reassuring.

- o Some of the gear used in preparing to fight in a chemical/biological environment will help. It will not, however, provide much protection against direct weapons effects or prolonged fall out.
- o A leak proof defense becomes far more important. Near to mid-term capabilities to provide such defense are far easier to postulate than deliver. It is unclear that they can be protected once an agent is disseminated. Study is needed of the extent to which air bases, key logistics, reception sites, and other areas involving heavy troop concentrations can be protected or kept functional.
- o Power projection forces cannot be fully prepared for nuclear conflict in many contingencies. Rapid dispersal, mobile warfare and operations in depth are only limited solutions. They are, however, better than no solutions at all. reduce vulnerability to biological warfare.
- o A strong deterrent and retaliatory offensive capability to reduce the risk of nuclear use, and to exact penalties for such use, will be even more important than is the case for biological warfare. It is doubtful, however, that conventional strike options can ever be lethal enough to underpin successful deterrence or prevent successful intimidation of friendly states..
- o A strong regional conventional retaliatory capability may increase the willingness of friendly states to resist intimidation and support power projection efforts, but much will depend on the lethality of the threat and the credibility of use.
- o If potential threat states acquire overt or proven nuclear warfare capabilities, this is likely to confront many friendly or moderate states with the choice of capitulation/accommodation or developing their own weapons of mass destruction. The only alternative may be a US or Western nuclear guarantee, applying the extended deterrence doctrine of the Cold War to regional warfare. This could potentially deal with the biological as well as the nuclear threat.

It should be noted that this list of lessons is similar in many ways to the lists of lessons for chemical and biological warfare. At the same time, there are important differences. Weapons of mass destruction are not similar in character and effect, and the lessons of war must be adapted accordingly. Perhaps the most serious difference between nuclear risks and other risks is that the real method of countering such capabilities does seem to be the tacit or overt threat of nuclear retaliation. Other measures may be adequate in dealing with relatively moderate regional nuclear powers, or in crises short of action high intensity conflict. Barring major technological breakthroughs in sensors and strike systems, it is doubtful they will be enough the moment regional nuclear use becomes a credible threat.

The Problem of Counter-Proliferation

Much of the discussion of the "revolution in military affairs" and the Gulf War ignores the faction that a "revolution in military affairs" that is shaped around conventional warfare may become obsolete before it is completed. The Gulf War is unlikely to be the last major regional conventional conflict. The pace of proliferation is sufficiently slow, and the risks of escalation to weapons of mass destruction are so great, that even most authoritarian and extremist regimes are likely to be reluctant to risk the use of weapons of mass destruction in many contingencies. Nevertheless, the first major regional contingency to make extensive use of biological weapons, to use even one nuclear weapon, or to conduct chemical attacks against civilian populations will change the nature of war far more than thermal sights or precision-guided weapons. Proliferation remains the greatest single threat to the kind of military superiority that the Coalition exploited during the Gulf War, as well as the greatest single threat to regional security in those areas where there is a growing prospect that extensive use may be made of chemical, biological, and nuclear weapons.

The US has reacted to this reality by making counterproliferation a major policy priority, and by restructuring its defense strategy accordingly. However, it is one thing to establish a policy, and another thing to make it work. Many Third World states covertly or overtly see proliferation as a means of overcoming their conventional inferiority, achieving status and military superiority, or dominating their region. Even many countries who sign arms control agreements may be as willing to violate them as Iraq was when it used chemical weapons against Iran and its own people. Many supplier states that can export dual capable and special purpose technologies give only limited and selective priority to export controls.

Few regional powers are ready to fund active and passive defenses against missiles and aircraft, and the chemical, biological, and nuclear weapons they can deliver. The US is the only Western power actively seeking to develop the power projection capabilities to fight in an NBC environment and its efforts are often severely limited by financial constraints. Intelligence support for counterproliferation often remains inadequate and politicized.

Europe and the UN lack the intelligence resources and sophisticated collection platforms to do more than provide limited amounts of human and technical intelligence. International agencies and arms control staffs often deal with military realities by denying the real world limits of what they can know and accomplish. The US has conducted a highly visible effort to improve its intelligence on proliferation, but much of this intelligence effort has done little more than produce bureaucratic turmoil and new staffs.

The quality of work is often questionable, and continues to suffer from many of the problems in US national intelligence efforts documented in Chapter Five.

US efforts to develop the technology for more effective counterproliferation are of uncertain quality. The US has examined a host of possible advances in technology that could produce improvements in intelligence, targeting, and damage assessment. Some -- like better defense equipment, detection systems, underground facility identification and kill capability -- have great potential. Other technologies are being treated as pork barrels, fiefdoms, and hobby shops.

Some counterproliferation efforts are tied to the same kind of limited scenarios and rigid assumptions about enemy behavior that crippled the Coalition effort to strike Iraq's nuclear capabilities. Counter-proliferation policy and analysis are sometimes approached with the same ideological biases that affected the debate over strategic defenses. Counterproliferation has become a growth industry where insufficient standards are often applied to intelligence analysis, contract research, cost factors, technical risk, deployment times, systems integration, and real world military capabilities. Even where resources are available, throwing money, manpower, and studies at a problem is not the same as solving it.

The scale and covert nature of Iraq's effort before the Gulf War is a warning that a successful counterproliferation policy must involve a mix of arms control regimes that err on the side of over-effectiveness and not ease of agreement. Export controls must be revitalized and enforced. At the same time, cooperative security and coalition warfare must take proliferation fully into account. Power projection capability must be fully ready to deal with weapons of mass destruction. Effective anti-tactical ballistic missile systems must be developed and deployed. Suitable defense and detection gear must be put into service. Dedicated efforts at deterrence must be made effective in high risk areas like the Korean peninsula and the Gulf. Dedicated warfighting capability must be developed and deployed. The West, and particularly the US, must have the intelligence, targeting plans and new targeting capabilities, weapons delivery systems, new weapons, and battle damage assessment capability to actually fight.

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[1] For a detailed description of this effort, see Annex Q of Department of Defense, Conduct of the Persian Gulf War, Final Report to Congress, Washington, Department of Defense, April, 1992. A detailed history of many of these events is provided in US Army Armament, Munitions, and Chemical Command, Legacy in the Sand: The United States Army Armament, Munitions, and Chemical Command in Operations Desert Shield and Desert Storm, Washington, GPO, 1993.

[2] GAO, Chemical and Biological Warfare: Use of Collective Protection on Vehicles, Aircraft, and Ships,"

GAO/NSIAD-91-273 FS, September, 1991.

[3] Department of Defense, Conduct of the Persian Gulf War, Final Report to Congress, Washington, Department of Defense, April, 1992, p. F-56.

[4] See GAO, "Chemical Warfare: Problems and Progress in Defense Capability," Washington, GAO/PEMD-86-11, July, 1986; GAO, "Chemical Warfare: Soldiers Inadequately Equipped and Trained to Conduct Chemical Operations," Washington, GAO/NSIAD-91-197, May, 1991; and GAO, "Chemical Warfare: Soldiers Not Adequately Trained or Equipped to Conduct Operations on A Chemical Battlefield," Washington, GAO/T-NSIAD-91-18, April 16, 1991.

[5] Department of Defense, Conduct of the Persian Gulf War, Final Report to Congress, Washington, Department of Defense, April, 1992, p. Q-9.

[6] GAO, "Operation Desert Storm: DoD Met Need for Chemical Suits and Masks, but Longer Term Actions Needed," Washington, GAO/NSIAD-92-116, April, 1992, pp. 3-4, 15, 20; Department of Defense, Conduct of the Persian Gulf War, Final Report to Congress, Washington, Department of Defense, April, 1992, p. Q-9.

[7] Significant differences of opinion exist among Army experts over the quality and safety of the M-17 and M-25 gas masks issued during Desert Storm. Some felt these masks had functional problems as well as ergonomic ones. The M-40 series consists of the M-40 personal protection mask and the M-42 combat vehicle mask, with built-in communications. The masks have silicone rubber face plates with in-turned periphery, binocular eye lens system, and an elastic head harness. Their features include front and side voice emitters, drink tube, clear and tinted outserts, and a filter canister with NATO-standard trends. The M-42 has a built-in microphone, connects to its canister with a hose, and has a butyl-covered hood to protect the face piece, head, and neck areas, The M-40 hood is compatible with the M-3 TAP protective suit and has a heavyweight butyl-covered fabric with a double skirt. See US Army, Weapons Systems: United States Army 1994, Department of the Army, Washington, OASA(RDA), SARD-SI, 1994, p. 55.

[8] GAO, "Operation Desert Storm: DoD Met Need for Chemical Suits and Masks, but Longer Term Actions Needed," Washington, GAO/NSIAD-92-116, April, 1992, pp. 3-4, 9-10, 16, 21-22.

[9] No differences of opinion emerged over the problems in the mask during Marine Corps testing. See Department of Defense, Conduct of the Persian Gulf War, Final Report to Congress, Washington, Department of Defense, April, 1992, p. Q-7.

[10] Department of Defense, Conduct of the Persian Gulf War, Final Report to Congress, Washington, Department of Defense, April, 1992, p. Q-9.

[11]Office of the Deputy Chief of Staff (Operations), Lessons Learned from Operation Desert Shield/Desert Storm, Department of the Army, July 19, 1991; GAO, "Chemical and Biological Defense: US Forces Are Not Adequately Equipped to Detect All Threats," Washington, GAO/NSIAD-93-2, January, 1993.

[12] Department of Defense, Conduct of the Persian Gulf War, Final Report to Congress, Washington, Department of Defense, April, 1992, p. Q-5.

[13] Department of Defense, Conduct of the Persian Gulf War, Final Report to Congress, Washington, Department of Defense, April, 1992, p. Q-9.

[14] US Army, Weapons Systems: United States Army 1994, Department of the Army, Washington, OASA(RDA), SARD-SI, 1994, p. 57; Department of Defense, Conduct of the Persian Gulf War, Final Report to Congress, Washington, Department of Defense, April, 1992, p. Q-5.

[15] US Army, Weapons Systems: United States Army 1994, Department of the Army, Washington, OASA(RDA), SARD-SI, 1994, p. 59; Department of Defense, Conduct of the Persian Gulf War, Final Report to Congress, Washington, Department of Defense, April, 1992, p. Q-5.

[16] GAO, "Chemical and Biological Defense: US Forces Are Not Adequately Equipped to Detect All Threats," Washington, GAO/NSIAD-93-2, January, 1993, p. 4.

[17] Based on interviews with senior Department of Defense officials serving during the Gulf War. Also see Department of Defense, Conduct of the Persian Gulf War: Final Report, Department of Defense, April, 1992, pp. 16-18.

[18] See GAO, "Operation Desert Storm: DoD Met Need for Chemical Suits and Masks, but Longer Term Actions Needed," Washington, GAO/NSIAD-92-116, April, 1992, pp. 3-4, 9-10, 16, 21-22.

[19] Department of Defense, Conduct of the Persian Gulf War, Final Report to Congress, Washington, Department of Defense, April, 1992, pp. Q-3 to Q-4.

[20] Based largely on interviews and magazine articles. For a detailed analysis of the impact on Coalition operations, see Lt. Colonel Jeffery D. McCausland, "How Iraq's CBW Threat Affected Coalition Operations," Defense and Foreign Affairs, September, 1992, pp. 12-16.

[21] See GAO, "Operation Desert Storm: DoD Met Need for Chemical Suits and Masks, but Longer Term Actions Needed," Washington, GAO/NSIAD-92-116, April, 1992, pp. 3-4, 9-10, 16, 21-22.

[22] Department of Defense, Conduct of the Persian Gulf War, Final Report to Congress, Washington, Department of Defense, April, 1992, p. Q-11.

[23] US Army Chemical and Biological Defense Command, Partnerships for CD Defense: Advance Planning Briefing for Industry," US Army, March 8-9, 1994; Chief of Naval Operations, "United States Navy Chemical, Biological, Radiological Defense Program, N86D, October, 1993.

[24] For a good retrospective on British capabilities, see Tim Otter, "Chemical Warfare Defense; Putting the Lessons of the Gulf War in Context," Military Technology, 12/1992, pp. 44-52. Also see US Army, Weapons Systems: United States Army 1994, Department of the Army, Washington, OASA(RDA), SARD-SI, 1994, p. 59; Department of Defense, Conduct of the Persian Gulf War, Final Report to Congress, Washington, Department of Defense, April, 1992, p. Q-5.

[25] See Gerald M. Steinberg, "Israeli Responses to the Threat of Chemical Warfare," BESA Center for Strategic Studies, Bar-Ilan University, Fall, 1993.

[26] Many of the following technical comments are based on interviews, various reporting in Jane's and Edward

L. Korb, The World's Missile Systems, Pomona, General Dynamics, 1988, pp. 245-244; Ray Bonds, Modern Soviet Weapons, New York, ARCO, 1986, pp., 88-89.

[27] David Wright and Timur Kadyshev, "The North Korean Missile Program: How Advanced Is It?," Arms Control Today, April, 1994, pp. 9-13.

[28] For details, see Jane's Soviet Intelligence Review, July, 1991, pp. 302-305.

[29] Preparing for launch includes a number of phases. These may be summarized as follows:

State	Warhead	Missile	TEL
6	in storage	in storage	available
5	in storage	sys/comp cks	available
4	attached	fueled	available
3	attached	put on TEL	move to site
2	attached	erected	set up
1	fused	launched	crew dispersed

All of the Scuds are liquid fueled and it normally takes a trained team around one hour to fuel and position the missile TEL (transporter-erector-launcher). It normally takes another hour to reload the launcher and an additional hour to prepare it for launching, not counting driving time to and from the reload site. A chemical warhead also has to be filled with the VX Agent. These warheads utilize pre-mixed agents that require crews in MOP gear to fill them.

[30] The author has seen Soviet publications with limited technical descriptions of the chemical warhead for the Scud in Arab countries, but no detailed design data.

[31] "US Reasserts Aim to Keep Oil Flowing From Persian Gulf," Washington Times (February 22, 1984), p. A-1.

[32] Baghdad has 23% of Iraq's population and is only 80 miles from the border. Tehran is about 290 miles from the front lines. "Iraqis Fire Missiles on Iranian Cities," Chicago Tribune (February 25, 1984), p. 20; Washington Post, May 11, 1988, p. A-1.

[33] Michael Eisenstadt, Like a Phoenix from the Ashes, Washington, Washington Institute Policy Paper No. 36, 1993, p. 36.

[34] "Hussein" or "Husayn" is the name of grandson of Muhammad and the son of Ali. Ali was martyred in An Najaf and Husayn in Karbala, both in Iraq.

[35] New York Times, May 1, 1988, p. 1; Los Angeles Times, May 21, 1988, p. 18; Washington Post, May 11, 1988, p. A-1.

[36] In spite of the knowledge gained during the Gulf War, sources still differ on other aspects of the performance of this system. According to some reports, the improved Iraqi Scuds have a CEP of 1,300 meters versus 1,000 meters for the Scud B, and carry only 600 kilograms versus 1,000 kilograms for the Scud B.

According to other reports, Iraq has obtained Scud Ds from the USSR, although this seems unlikely. The Scud Ds are substantially more accurate than the Scud C, and can use minelet and submunition payloads, but there is no evidence the USSR has sold such systems to Third World states. Some reports indicate that Iraq has Soviet-made Scud C missiles with strap on boosters. This seems doubtful because the missiles Iran recovered did not have such boosters, only a smaller warhead. David C. Isby, Weapons and Tactics of the Soviet Army, Fully Revised Edition, London, Jane's, 1988, pp. 296-301; For details, see Jane's Soviet Intelligence Review, May, 1990, pp. 204-209 and June 1990, pp. 242-248; Aviation Week, January 28, 1991, p. 28; International Defense Review, November, 1988, pp. 1423-1427.

[37] Working paper issued by the Israeli Embassy in Washington, April, 1990. No author, title, or publisher listed. Also see Duncan Lennox, "Iraq-Ballistic Missiles", Current News, Supplement, Department of Defense, October 11, 1990, pp. B-4 to B-6; Washington Post, October 10, 1990, p. 19; Dick Palowski, Changes in Threat Air Combat Doctrine and Force Structure, 24th Edition, Fort Worth, General Dynamics DWIC-01, February, 1992, pp. II-330 to II-331; San Diego Navy Dispatch, September 8, 1990, p. 26; DAH-90, December 1989, p. 30..

[38] Based on interviews.

[39] There are substantial differences in the count of missiles launched. The Department of Defense refers to "almost 200" in Department of Defense, Conduct of the Persian Gulf War: Final Report, Department of Defense, April, 1992, pp. 13-15. Also see the author's detailed tables in Lessons of Modern War, Volume II: The Iran-Iraq War, Boulder, 1991, pp. 364, 366, 405, 496-502, 524, 599. The author counts a total of 203 missiles, and over 160 fired at Tehran.

[40] Martin Navias, "Ballistic Missile Proliferation in the Middle East," Survival, May/June 1989, p. 228; Warren W. Lenhard and Todd Masse, "Persian Gulf War: Iraqi Scud Ballistic Missile Systems, " Washington, Congressional Research Service 71-173F. February 14, 1991, p. CRS-3; Department of Defense, Conduct of the Persian Gulf War: Final Report, Department of Defense, April, 1992, pp. 16-19.

[41] Theodore A. Postal, "Lessons of the Gulf War Experience with Patriot," International Security, Winter 1991-1992, pp. 128-129.

[42] Rick Atkinson, Crusade, pp. 181-183

[43] FBIS, Middle East, April 25, 1988, p. 1; Duncan Lennox, "Iraq-Ballistic Missiles", Current News, Supplement, Department of Defense, October 11, 1990, pp. B-4 to B-6.

[44]Department of Defense, Conduct of the Persian Gulf War: Final Report, Department of Defense, April, 1992, pp. 16-18; Defense and Foreign Affairs Weekly, May 8-14, 1989, pp. 3 and 6. Iraq's Minister of Industry and Military Industrialization, Husayn Kamil, has denied Iraq is cooperating in missile development with any foreign country. Jane's Defense Weekly, May 13, 1989, p. 843.

[45] New York Times, November 12, 1991, p. A-3; Department of Defense, Conduct of the Persian Gulf War: Final Report, Department of Defense, April, 1992, pp. 16-18.

[46] Department of Defense, Conduct of the Persian Gulf War: Final Report, Department of Defense, April, 1992, pp. 16-18; New York Times, September 7, 1989, p. A-9; New York Times, March 30, 1990, p. 6, April 3, 1990, p. 1, November 12, 1991, p. A-3; Christian Science Monitor, January 23, 1992, p. 1; The Atlanta Constitution, January 16, 1992, p. 1

[47] For a good summary report, see Jane's Defense Weekly, February 17, 1990, p. 295. Also see Financial Times, November 21, 1989, p. 1; Washington Post, September 20, 1989.

[48] Flight International, May 13, 1989, p. 20; Wall Street Journal, August 30, 1990.

[49] William Lowther Iraq and the Supergun, London, Pan, 1992, especially pages 210-215.

[50] Department of Defense, Conduct of the Persian Gulf War: Final Report, Department of Defense, April, 1992, pp. 19. Some sources indicate that the booster is called the al-Abbid or Worshipper.

[51] The Middle East, November, 1989, p. 19; William Lowther Iraq and the Supergun, London, Pan, 1992, pp. 257-258.

[52] Department of Defense, Conduct of the Persian Gulf War: Final Report, Department of Defense, April, 1992, pp. 16-18; New York Times, September 7, 1989, p. A-9.

[53] Duncan Lennox, "Iraq-Ballistic Missiles", Current News, Supplement, Department of Defense, October 11, 1990, pp. B-4 to B-6.

[54] New York Times, December 5, 1989; Washington Post, December 9, 1989; Aviation Week, December 11, 1989, p. 31; Defense Daily, December 12, 1989, p. 381; Financial Times, December 20, 1989, p; FBIS-WES, December 8, 1989, p. 23; Jane's Defense Weekly, December 23, 1989, pp. 1371-1372.

[55] Reuters, October 4, 1991, AM Cycle.

[56] New York Times, April 24, 1990, p. 13; Washington Times, May 30, 1990, July 10, 1990.

[57] See W. Andrew Terrill, "The Gulf War and Ballistic Missile Proliferation," Comparative Strategy, V.11, 1992, pp. 163-176.

[58] Washington Post, October 10, 1990, p. 19; Financial Times (London), October 10, 1990, p. 7.

[59] For an interesting summary of estimates of Scud capability at the time of the war, see Warren W. Lenhard and Todd Masse, "Persian Gulf War: Iraqi Scud Ballistic Missile Systems," Washington, Congressional Research Service 91-173F, February 14, 1991.

[60] The UN has only had formal acknowledgment from Iraq of 10 Soviet MAZ-543, six al-Nida, and three al-Walid launchers, and 11 decoy launchers. Michael Eisenstadt, Like A Phoenix from the Ashes, Washington, Washington Institute Policy Paper No. 36, p. 36.

[61] There is still considerable uncertainty as to how many mobile launchers Iraq had operational in January 199l, and estimates generally range from 15-30. Most seem to have been MAZ-543s, but some may have been Iraqi-made mobile launchers.

[62] Duncan Lennox, "Iraq-Ballistic Missiles", Current News, Supplement, Department of Defense, October 11, 1990, pp. B-4 to B-6. Some sources claim Iraq had up to 100-225 home-made launchers by the time of the

war, and that the US firm of Terex in Bridgeport, Connecticut, assisted Iraq in making these units. New York Times, January 26, 1992, p. A-12. In practice, Iraq seems to have deployed only a about six a-Nida TELs, three Al-Walid TELs, and nine decoy launchers. Michael Eisenstadt, Like A Phoenix from the Ashes, Washington, Washington Institute Policy Paper No. 36, p. 36; UN Press Release, IK/79, December 16, 1991; UN Press Release IK/128, November 5, 1992, pp. 1-2.

[63] UN Press Release, IK/79, December 16, 1991; UN Press Release IK/128, November 5, 1992, pp. 1-2; Michael Eisenstadt, Like A Phoenix from the Ashes, Washington, Washington Institute Policy Paper No. 36, p. 36.

[64] Washington Times, March 29, 1990, pp. A-1 and A-8; April 29, 1990; Washington Post, April 30, 1990; Jane's Defense Weekly, October 29, 1988, p. 1045; New York Times, March 30, 1990, p. A-6.

[65] US Navy working paper, August, 1990. The sites were Wadi al Jabaryah, Luadl or Ratqa, H-2, Wadi Amil, Ishuayb al Awaj, Qasr Amij East, Qasr Amij West, Wadi Hawran, and Zawr Hawran.

[66] Dick Palowski, Changes in Threat Air Combat Doctrine and Force Structure, 24th Edition, Fort Worth, General Dynamics DWIC-01, February, 1992, p. II-332, UK Recognition Journal, October, 1988, p. 312.

[67] See the deliberate furor Saddam Hussein created over the fixed sites in March, 1990. New York Times, March 30, 1990. p. 6.

[68] Rick Atkinson, Crusade, p. 144.

[69] For typical reporting see Sir Peter de la Billiere, Storm Command, pp. 210-211; Molly Moore, A Woman at War, New York, Scribners, 1993, pp. 102-103; General Pagonis, Moving Mountains, pp. 148-149.

[70] For a detailed description of the effect of the Scud hit on the Dhahran barracks, see United States News and World Report, Triumph Without Victory, New York, Random House, 1992, pp. 328-330.

[71] Widely different figures on the level of physical damage done in Israel have been published in various sources. see Theodore A. Postal, "Lessons of the Gulf War Experience with Patriot," International Security, Winter 1991-1992, pp. 139-151 for high damage estimates and a useful chronology of damage effects in Israel. For a very different examination of the damage effects from the Scud attacks, see Steve Fedtter, George N. Lewis, and Lisbeth Gronlund, "Why were Scud Casualties so low?" Nature, Vol. 361, January 28, 1993, pp. 293-296.

[72] Iran has claimed that each Scud that feel on Tehran killed 10-15 and injured at least 30, but these claims are dubious. Steve Fedtter, George N. Lewis, and Lisbeth Gronlund, "Why were Scud Casualties so low?" Nature, Vol. 361, January 28, 1993, pp. 293-296.

[73] For good accounts of these impacts, see General H. Norman Schwarzkopf, It Doesn't Take a Hero, pp. 409, 415-421, 430, 430, e452, 460-461, 470-472, and 475; also see Rick Atkinson, Crusade, pp. 18, 33, 38-50, 66, 81-85, 90-94, 96-103, 124-126, 144-148, 173-175, 181-182, 217-218, 222, 232, 277-278, 417, 496.

[74] Washington Post, July 26, 1991, p. A-1; "Ambassador Rolf Ekrus, "Unearthing Iraq's Arsenal," Arms Control Today, April 1992, pp. 6-9.

[75]The UN refused to name the facilities at the time of this declaration because it feared this would allow Iraqi to move some of the equipment and missiles in them. Washington Post, February 14, 1992, p. A-33.

[76] Washington Post, February 14, 1992, p. A-33; Washington Post, January 15, 1992, p. A-18.

[77] Christian Science Monitor, January 23, 1992, p. 1.

[78] The Atlanta Constitution, January 16, 1992, p. 1; New York Times, February 28, 1992, p. A-28, November 5, 1992, p. A-10; Washington Times, February 11, 1992, p.1, November 6 ,1992, p. A-7; Washington Post, January 27, 1993, p. A-16, July 7, 1993, p. A-28; Philadelphia Inquirer, March 16, 1993, p. E-1; Arms Control Today, December, 1992, p. 24; .

[79] Washington Post, January 15, 1992, p. A-18; Washington Times, September 12, 1991, p. A8; March 5, 1992, p. 1. US News and World Report published an article claiming that Iraq might have an underground factory and some 800 missiles on February 10, 1992 (p.22). General Colin Powell later indicated that he had seen no evidence of any underground facility and that Iraq's maximum holding might be about 250 missiles. Albany Times Union, February 5, 1992, p. 7.

[80] New York Times, February 28, 1992, p. 28; Washington Times, February 11, 1992, p.1, November 6 ,1992, p. A-7.

[81] Michael Eisenstadt, Like A Phoenix from the Ashes, Washington, Washington Institute Policy Paper No. 36, pp. 36-37.

[82] Michael Eisenstadt, Like A Phoenix from the Ashes, Washington, Washington Institute Policy Paper No. 36, p. 37

[83] The US is considering modifying its own drones to use GPS to achieve such accuracies. Defense Week, January 3, 1994, p. 1.

[84] Jane's Defense Weekly, 30 January 1993, pp. 20-21; Defense Electronics and Computing, IDR press, September 1992, pp. 115-120, International Defense Review, May, 1992, pp. 413-415; Jane's Remotely Piloted Vehicles, 1991-1992; Keith Munson, World Unmanned Aircraft, London, Jane's 1988; Air Force Magazine, March, 1992, pp. 94-99, May, 1992, p. 155.

[85] Eliot Cohen, ed., Gulf War Air Power Survey, Volume II, Part II,, p. 335-336. See footnotes on these pages.

[86] Interviews, Schwarzkopf, It Doesn't Take A Hero, pp. 416-421; and Rick Atkinson, Crusade, pp. 96-97, 124-127, 145-148,174-175, 221-222; New York Times, February 12, 1991.

[87] Figures of up to 2,500 sorties have been estimated. This higher total includes sensors as well as strike sorties, and sorties that were diverted to other targets when Scud targets could not be "found".

[88] Eliot Cohen, ed., Gulf War Air Power Survey, Volume IV, Part I, p. 341.

[89] Rick Atkinson, Crusade, pp. 147-148, 177-181, 232-233.

[90] Figures of up to 2,500 sorties have been estimated. This higher total includes sensors as well as strike sorties, and sorties that were diverted to other targets when Scud targets could not be "found".

[91] Eliot Cohen, ed., Gulf War Air Power Survey, Volume II, Part II, pp. 331-332.

[92] A-10s claimed 51 launcher kills and F-15Es claimed 6-10. Eliot Cohen, ed., Gulf War Air Power Survey, Volume II, Part II, pp. 330-331.

[93] Thomas A. Keaney and Eliot A. Cohen, Gulf War Air Power Survey: Summary Report, Washington, Department of the Air Force, 1993, pp. 124.

[94] Eliot Cohen, ed., Gulf War Air Power Survey, Volume II, Part II, p. 330.

[95] The broader operational, intelligence and BDA problems that created additional problems in targeting the Scuds have been described in Chapter Five and many of the related problems in air operations have been discussed in Chapter Seven.

[96] Eliot Cohen, ed., Gulf War Air Power Survey, Volume II, Part II, p. 333.

[97] Department of Defense, Conduct of the Persian Gulf War: Final Report, Department of Defense, April, 1992, p. 167; Thomas A. Keaney and Eliot A. Cohen, Gulf War Air Power Survey: Summary Report, Washington, Department of the Air Force, 1993, pp. 124.

[98] Eliot Cohen, ed., Gulf War Air Power Survey, Volume II, Part II, pp. 331, 334-336, 340; Brigadier General Robert H. Scales, Certain Victory, pp. 184.

[99] These data are deliberately kept unclassified. For more details see Graham Smith, Weapons of the Gulf War, London, Salamander Book, 1991, pp. 11-12

[100] Eliot Cohen, ed., Gulf War Air Power Survey, Volume II, Part II,, p. 335-336. see footnotes on these pages.

[101] Eliot Cohen, ed., Gulf War Air Power Survey, Volume II, Part II,, p. 336.

[102] Eliot Cohen, ed., Gulf War Air Power Survey, Volume II, Part II, pp. 331, 334-336, 340; Brigadier General Robert H. Scales, Certain Victory, pp. 184.

[103] See Chapter Five.

[104] See the deliberate furor Saddam Hussein created over the fixed sites in March, 1990. New York Times, March 30, 1990. p. 6.

[105] Eliot Cohen, ed., Gulf War Air Power Survey, Volume II, Part II,, p. 339. For contrasting views see Stewart M. Powell, "Scud War, Round Two," Air Force, April, 1992, pp. 48-53, and "Scud War, Round Three," Air Force, October, 1992, pp. 32-35.

[106] Eliot Cohen, ed., Gulf War Air Power Survey, Volume II, Part II, pp. 335-338; Volume IV, Part I, pp. 336-339.

[107] Eliot Cohen, ed., Gulf War Air Power Survey, Volume IV, Part I, pp. 290-294.

[108] For an unclassified summary see Eliot Cohen, ed., Gulf War Air Power Survey, Volume IV, Part I, pp. 293-295.

[109] A great deal of conflicting material is available on the performance of Patriot during the Gulf War. The best unclassified source is US Congress, Committee on Appropriations, Subcommittee on the Department of Defense, Hearings on the FY1993 Defense Budget, April, 1991; "Performance of the Patriot Missile in the

Gulf War," Hearing Before The Legislation and National Security Subcommittee of the Committee on Government Operations, House of Representatives, 102 Congress, Second Session, April 7, 1992. Also see President George Bush, speech to Raytheon Missile Systems Plant, February 15, 1991. Theodore A. Postal, "Lessons of the Gulf War Experience with Patriot," International Security, Winter 1991-1992, pp. 112-131; Robert M. Stein, and Theodore A. Postal, " Correspondence: Patriot Experience in the Gulf War," International Security, Summer 1992, pp. 199-240; Steven A. Hildreth, "Theater Ballistic Missile Defense," CRS 93-585F, June 10, 1993; Steven A. Hildreth and Paul C. Zinsmeister, "The Patriot Air Defense System and the Search for an Anti-Tactical Ballistic Missile System, CRS 91-456F, June 18, 1991; General Accounting Office, "Patriot Missile Defense: Software Problem Led to System Failure at Dhahran," Saud Arabia, GAO/IMTEC-92-26, February, 1992; Rep. John Conyers Jr., "The Patriot Myth: Caveat Emptor," Arms Control Today, Vol. 22, No. 9, November, 1992; Jorg Bahnemann and Thomas Enders, "Reconsider Ballistic Missile Defense," Military Technology, 4/91, pp. 46-52; Statement of Ted A. Postol, "Optical Evidence Indicating Patriot High Miss Rates During the Gulf War," Committee on Government Operations, Subcommittee on Legislation and National Security, April 7, 1992; Rep. John Conyers Jr., "The Patriot Myth: Caveat Emptor," Arms Control Today, Vol. 22, No. 9, November, 1992, pp. 4-5; Eric H. Arnett, "Issue Paper: Ballistic Missile Defense After the Kuwait War," Washington, American Academy for the Advancement of Science, 91-15S, July, 1991; unclassified chronology in Eliot Cohen, ed., The Gulf War Air Power Survey, Part V, Part II; Jorg Bahnemann and Thomas Enders, "Reconsider Ballistic Missile Defense," Military Technology, 4/91, pp. 46-52.

[110] US Army press release, "Army Weapons System Performance in Southwest Asia, March 13, 1991, p. 3. The press release did note that the Patriot only engaged "threatening" Scuds.

[111] James F. Dunnigan and Austin Bay, From Shield to Storm, New York, William Morrow & Co., 1992, pp. 186-187; Army Magazine, March, 1991, pp. 40-42. More detailed, but speculative specifications are provided in Theodore A. Postal, "Lessons of the Gulf War Experience with Patriot," International Security, Winter 1991-1992, pp. 12126.

[112] Aviation Week, February 18, 1991, p. 49.

[113] James F. Dunnigan and Austin Bay, From Shield to Storm, New York, William Morrow & Co., 1992, pp. 186-187; Army Magazine, March, 1991, pp. 40-42.

[114] Steven A. Hildreth and Paul C. Zinsmeister, "The Patriot Air Defense System and the Search for an Anti-Tactical Ballistic Missile System, CRS 91-456F, June 18, 1991, pp. CRS-11; Army Magazine, March, 1991, pp. 40-42; Aviation Week, January 28, 1991, pp. 26-27.

[115] Army Magazine, March, 1991, p. 42; Aviation Week, January 28, 1991, pp. 26-27.

[116] For a brief description of the Patriot and its role in the ABM debate, see Richard Halloran, pp. 300-302; Steven A. Hildreth and Paul C. Zinsmeister, "The Patriot Air Defense System and the Search for an Anti-Tactical Ballistic Missile System, CRS 91-456F, June 18, 1991, pp. CRS-10 to CRS-13.

[117] Steven A. Hildreth and Paul C. Zinsmeister, "The Patriot Air Defense System and the Search for an Anti-Tactical Ballistic Missile System, CRS 91-456F, June 18, 1991, pp. CRS-11; Army Magazine, March, 1991, pp. 40-42; Aviation Week, January 28, 1991, pp. 26-27.

[118] Defense News, December 3, 1990, p. 347.

[119] Eric H. Arnett, "Issue Paper: Ballistic Missile Defense After the Kuwait War," Washington, American Academy for the Advancement of Science, 91-15S, July, 1991, p. 6.

[120] Aviation Week, February 18, 1991, p. 49.

[121] The precise chronology and nature of the Patriot readiness problem is classified. However, a partial list of daily readiness problems is listed in the unclassified chronology in Eliot Cohen, ed., The Gulf War Air Power Survey, Part V, Part II. Also see Eric H. Arnett, "Issue Paper: Ballistic Missile Defense After the Kuwait War," Washington, American Academy for the Advancement of Science, 91-15S, July, 1991, and Rick Atkinson, Crusade, pp. 416-417, and General Accounting Office, "Patriot Missile Defense: Software Problem Led to System Failure at Dhahran," Saud Arabia, GAO/IMTEC-92-26, February, 1992; New York Times, June 6, 1991, p. A-9. Robert M. Stein, and Theodore A. Postal, " Correspondence: Patriot Experience in the Gulf War," International Security, Summer 1992, pp. 199-240; Theodore A. Postal, "Lessons of the Gulf War Experience with Patriot," International Security, Winter 1991-1992, pp. 135-136.

[122] Rick Atkinson, Crusade, pp. 416-417; Brigadier General Robert H. Scales, Certain Victory, pp. 71, 124-125, 182-183.

[123] Aviation Week, February 18, 1991, p. 49.

[124] These data are drawn from interviews with contractor, US Army and IDF personnel. For an analysis of the time problem which is critical of the Patriot see the debates in US Congress, Committee on Appropriations, Subcommittee on the Department of Defense, Hearings on the FY1993 Defense Budget, April, 1991; "Performance of the Patriot Missile in the Gulf War," Hearing Before The Legislation and National Security Subcommittee of the Committee on Government Operations, House of Representatives, 102 Congress, Second Session, April 7, 1992 (especially, pages 105-107). Also see Theodore A. Postal, "Lessons of the Gulf War Experience with Patriot," International Security, Winter 1991-1992, pp. 132-134.

[125] See the Army testimony in US Congress, Committee on Appropriations, Subcommittee on the Department of Defense, Hearings on the FY1993 Defense Budget, April, 1991; "Performance of the Patriot Missile in the Gulf War," Hearing Before The Legislation and National Security Subcommittee of the Committee on Government Operations, House of Representatives, 102 Congress, Second Session, April 7, 1992, and Aviation Week, February 18, 1991, p. 50.

[126] Based on interviews with Israeli and US Army experts, US Army working paper, and Jane's Defense Weekly, April 27, 1991, p. 677; New York Times, October 31, 1991, p. A-8; November 21, 1993, p. A-13; Defense News, February 18, 1991, p. 35, and the debates in US Congress, Committee on Appropriations, Subcommittee on the Department of Defense, Hearings on the FY1993 Defense Budget, April, 1991;

"Performance of the Patriot Missile in the Gulf War," Hearing Before The Legislation and National Security Subcommittee of the Committee on Government Operations, House of Representatives, 102 Congress, Second Session, April 7, 1992.

[127] Theodore A. Postal, "Lessons of the Gulf War Experience with Patriot," International Security, Winter 1991-1992, pp. 154.

[128] See Robert M. Stein, and Theodore A. Postal, " Correspondence: Patriot Experience in the Gulf War," International Security, Summer 1992, pp. 199-240; Eric H. Arnett, "Issue Paper: Ballistic Missile Defense After the Kuwait War," Washington, American Academy for the Advancement of Science, 91-15S, July, 1991, p. 8; interviews with Israeli and US Army experts, US Army working paper, and Jane's Defense Weekly, April 27, 1991, p. 677; New York Times, October 31, 1991, p. A-8; November 21, 1993, p. A-13.

[129] The precise chronology and nature of the Patriot readiness problem is classified. However, a partial list of daily readiness problems is listed in the unclassified chronology in Eliot Cohen, ed., The Gulf War Air Power Survey, Part V, Part II. Also see Eric H. Arnett, "Issue Paper: Ballistic Missile Defense After the Kuwait War," Washington, American Academy for the Advancement of Science, 91-15S, July, 1991, and Rick Atkinson, Crusade, pp. 416-417, and General Accounting Office, "Patriot Missile Defense: Software Problem Led to System Failure at Dhahran," Saud Arabia, GAO/IMTEC-92-26, February, 1992; New York Times, June 6, 1991, p. A-9. Robert M. Stein refers to two sets of changes in Robert M. Stein, and Theodore A. Postal, " Correspondence: Patriot Experience in the Gulf War," International Security, Summer 1992, pp. 199-240; Theodore A. Postal, "Lessons of the Gulf War Experience with Patriot," International Security, Winter 1991-1992, pp. 135-136. Theodore A. Postal refers to three sets of upgrades in, "Lessons of the Gulf War Experience with Patriot," International Security, Winter 1991-1992, pp. 132-134. Interviews with some US Army personnel indicate there were four.

[130] Sources disagree over whether the Version 35 software that attempted to deal with all of these changes was based in part on Israeli tests and technical data. Based on interviews with Israeli and US Army experts, Robert M. Stein, and Theodore A. Postal, " Correspondence: Patriot Experience in the Gulf War," International Security, Summer 1992, pp. 199-240; and Theodore A. Postal, "Lessons of the Gulf War Experience with Patriot," International Security, Winter 1991-1992, pp. 155-157.

[131] Rick Atkinson, Crusade, pp. 181-183; General Accounting Office, "Patriot Missile Defense: Software Problem Led to System Failure at Dhahran," Saud Arabia, GAO/IMTEC-92-26, February, 1992; Robert M. Stein " Correspondence: Patriot Experience in the Gulf War," International Security, Summer 1992, pp. 211-213.

[132] See "Performance of the Patriot Missile in the Gulf War," Hearing Before The Legislation and National Security Subcommittee of the Committee on Government Operations, House of Representatives, 102 Congress, Second Session, April 7, 1992, and Aviation Week, February 18, 1991. US Army testimony, however, still defended the impression left by the original data in 1992. See testimony of Major General; Jay

M. Garner before the Subcommittee of Legislative and National Security, Committee on Government Operations, House of Representatives, April 7, 1992. Marvin Feurwerger provides a good discussion of the contradiction in the data in "Defense Against Missiles, Patriot Lessons," Orbis, Fall, 1992, pp. 581-589.

[133] "Performance of the Patriot Missile in the Gulf War," Hearing Before The Legislation and National Security Subcommittee of the Committee on Government Operations, House of Representatives, 102 Congress, Second Session, April 7, 1992, pp. 14-16, and Aviation Week, February 18, 1991.

[134] A total of 14 portable data recorders were available for 20 batteries in Saudi Arabia and six in Israel, and many were not installed or were installed late in the war. Postal states that US Army commanders in Saudi Arabia did not allow the units to be installed after a missile firing failed shortly after a recorder was installed. Stein disagrees. see Science, November 8, 1991, p. 79; Robert M. Stein, " Correspondence: Patriot Experience in the Gulf War," International Security, Summer 1992, p. 215; Theodore A. Postal, "Lessons of the Gulf War Experience with Patriot," International Security, Winter 1991-1992, pp. 135-136.

[135] Interviews in Israel, and Theodore A. Postal, "Lessons of the Gulf War Experience with Patriot," International Security, Winter 1991-1992, pp. 137.

[136] Robert M. Stein, and Theodore A. Postal, " Correspondence: Patriot Experience in the Gulf War," International Security, Summer 1992, pp. 199-240; Theodore A. Postal, "Lessons of the Gulf War Experience with Patriot," International Security, Winter 1991-1992, pp. 135-136.

[137] "Performance of the Patriot Missile in the Gulf War," Hearing Before The Legislation and National Security Subcommittee of the Committee on Government Operations, House of Representatives, 102 Congress, Second Session, April 7, 1992, p. 16..

[138] "Performance of the Patriot Missile in the Gulf War," Hearing Before The Legislation and National Security Subcommittee of the Committee on Government Operations, House of Representatives, 102 Congress, Second Session, April 7, 1992, p. 17-18, 29-30.

[139] See US General Accounting Office, "Operation Desert Storm: Data Does Not Exist to Conclusively Say How Well Patriot Performed," Washington, GAO, September, 1992; Rick Atkinson, Crusade, pp. 278-279.

[140] The reader is invited to wade through the full details of this debate in Robert M. Stein, and Theodore A. Postal, " Correspondence: Patriot Experience in the Gulf War," International Security, Summer 1992, pp. 199-240; Theodore A. Postal, "Lessons of the Gulf War Experience with Patriot," International Security, Winter 1991-1992, pp. 135-136; and "Performance of the Patriot Missile in the Gulf War," Hearing Before The Legislation and National Security Subcommittee of the Committee on Government Operations, House of Representatives, 102 Congress, Second Session, April 7, 1992, and attempt to make his or her own judgment.

[141] For a realistic examination of this issue, see Steve Fedtter, George N. Lewis, and Lisbeth Gronlund, "Why were Scud Casualties so low?" Nature, Vol. 361, January 28, 1993, pp. 293-296.

[142] Interviews and Jane's Defense Weekly, April 27, 1991, p. 677.

[143] See the debate in "Performance of the Patriot Missile in the Gulf War," Hearing Before The Legislation

and National Security Subcommittee of the Committee on Government Operations, House of Representatives, 102 Congress, Second Session, April 7, 1992, pp. 105-108.

[144] See Steven A. Hildreth, "Theater Ballistic Missile Defense," CRS 93-585F, June 10, 1993, p. CRS-10, and Rep. John Conyers Jr., "The Patriot Myth: Caveat Emptor," Arms Control Today, Vol. 22, No. 9, November, 1992, pp. 4-5; Rick Atkinson, Crusade, pp. 278-279.

[145] "Performance of the Patriot Missile in the Gulf War," Hearing Before The Legislation and National Security Subcommittee of the Committee on Government Operations, House of Representatives, 102 Congress, Second Session, April 7, 1992, pp. 1114-115.

[146] "Performance of the Patriot Missile in the Gulf War," Hearing Before The Legislation and National Security Subcommittee of the Committee on Government Operations, House of Representatives, 102 Congress, Second Session, April 7, 1992, pp. 118-130, 227-229. Also see GAO, "Operation Desert Storm: Data Does Not Exist to Conclusively Say How Well Patriot Performed," GAO/NSIAD-92-340, September, 1992 and "Operation Desert Storm: Project Manager's Assessment of Patriot Missile's Overall Performance is not Support," GAO/NSIAD-92-27, April 7, 1992.

[147] Quoted in Defense Electronics, October, 1993, p. 16; Jane's Defense Weekly, April 6, 1991, p. 519.

[148] This discussion is drawn from the material provided in Ballistic Missile Defense Organization (BMDO), 1994 Report to Congress on Ballistic Missile Defense, Washington, BMDO, Department of Defense, July, 1994, pp. 2-8 to 2-10.

[149] US Army, Weapons Systems: United States Army 1994, Department of the Army, Washington, OASA(RDA), SARD-SI, 1994, pp. 61-63; Ballistic Missile Defense Organization (BMDO), 1994 Report to Congress on Ballistic Missile Defense, Washington, BMDO, Department of Defense, July, 1994, pp. 2-16 to 2-18; Jane's Defense Weekly, October 26, 1991, p. 749. Eric H. Arnett, "Issue Paper: Ballistic Missile Defense After the Kuwait War," Washington, American Academy for the Advancement of Science, 91-15S, July, 1991, p. 8; Defense News, January 24, 1994, p. 1; Army, December, 1993, p. 32.

[150] Some reports indicate the use of millimeter wave seekers and 180 small rockets to achieve a direct collision.

[151] US Army, Weapons Systems: United States Army 1994, Department of the Army, Washington, OASA(RDA), SARD-SI, 1994, pp. 61-63; Eric H. Arnett, "Issue Paper: Ballistic Missile Defense After the Kuwait War," Washington, American Academy for the Advancement of Science, 91-15S, July, 1991, p. 8; Defense News, January 24, 1994, p. 1; Orlando Sentinel, June 17, 1993, p. C-1; Army, December, 1993, pp. 31-36; Boston Globe, March 23, 1994, p. 1.

[152] The most authoritative summary available at this writing is Ballistic Missile Defense Organization (BMDO), 1994 Report to Congress on Ballistic Missile Defense, Washington, BMDO, Department of Defense, July, 1994, pp. 2-8 to 2-10. Note, however, that Congressional action on the defense budget produces significant changes to the programs proposed by the Department of Defense.

[153] US Army, Weapons Systems: United States Army 1994, Department of the Army, Washington, OASA(RDA), SARD-SI, 1994, pp. 72-73.

[154] Aviation Week, June 7, 1993, p. 133 and October 11, 1993, p. 53; Steven A. Hildreth, "Theater Ballistic Missile Defense," CRS 93-585F, June 10, 1993, p. CRS-10; Defense News, November 8, 1993, p. 18, February 7, 1994, p. 6.

[155] Alan George, "Missile Blueprint reveals Iraqi Supergun plan," Flight International, June 22, 1994, p. 4; Washington Times, June 27, 1994, p. A-15.

[156] Considerable debate has taken place since the war as to whether British officials knew about the gun much earlier and could have prevented earlier deliveries of equipment to Iraq. Washington Post, January 16, 1992, p. 11; London Financial Times, January 22, 1992, p. 6.

[157] Project Harp had tested a gun based on combining two 16" guns bored out to a caliber of 16.69 inches with a total caliber length of L/86. This project demonstrated that such a device could launch 185 pound payloads up to altitudes of 118 miles (200 kilometers).

[158] William Lowther Iraq and the Supergun, London, Pan, 1992, pp. 226.

[159] Bull had claimed that such a device using a solid propellant rocket could deliver a 272 kilogram payload to ranges of 1,150 miles (1,852 kilometers), and 90 kilograms to 2,000 miles (3,200) kilometers. In addition, to helping Israel develop 175mm guns rounds that reached ranges of 40 kilometers, Bull and SRC had previously helped Iraq develop its own Majnoon 155mm and Al Faw 210mm artillery weapons. Jane's Defense Weekly, April 28, 1990, pp. 770-771, June 2, 1990, p. 1063; Washington Post, April 19, 1990, p. A-37; Economist, May 5,1990, p. 99; Aviation Week, May 7, 1990, p. 88; Nature, April 26, 1990, p. 811.

[160] The blue prints for the missile indicated that its launch weight was 412.53 kilograms, including 225 kilograms of solid fuel, a 40.18 kilogram Kevlar casing, a nozzle assembly weighing 23.61 kilograms, a guidance and control package weighing 23.2 kilograms, and a payload case weighing 24/93 kilograms.

[161] Alan George, "Missile Blueprint reveals Iraqi Supergun plan," Flight International, June 22, 1994, p. 4; Washington Times, June 27, 1994, p. A-15.

[162] The gun was aimed in the general direction of Israel. Jane's Defense Weekly, April 24, 1990, November 24, 1990, September 14, 1991, pp. 458-459; Defense News, November 11, 1991, p. 4; US News and World Report, November 25, 1991, p. 36; Department of Defense, Conduct of the Persian Gulf War: Final Report, Department of Defense, April, 1992, pp. 16-18; New York Times, September 7, 1989, p. A-9.

[163] Some sources estimate a barrel length of 153-160 meters. Nature, April 26, 1990, p. 811; International Defense Review, 5/1990, p. 481; Financial Times, April 18, 1990, p. 22, May 2, 1990, p. 18; The Middle East, March, 1990, pp. 17-18.

[164] Jane's Defense Weekly, September 14, 1991, pp. 458-459; Defense News, November 11, 1991, p. 4; Philadelphia Inquirer, October 9, 1991, p. 12.

[165] Philadelphia Inquirer, October 9, 1991, p. 12; US News and World Report, November 25, 1991, p. 36.

[166] See William Lowther's Iraq and the Supergun, London, Pan, 1992, especially pages 226-227.

[167] Space Research Corporation had also done extensive work for Israel. Other firms involved may have included Societa delle Funcine, Firpas SrL and Italian Technology Innovation SrL of Italy; Amalgamated Trading Industries of Belgium; Advanced Technology Institute of Athens; PRB of Belgium, and Astra Defense Systems of the UK. It is uncertain how many of these firms were knowingly involved, if they were involved at all. . Jane's Defense Weekly, April 28, 1990, pp. 770-771; Washington Post, April 19, 1990, p. A-37; London Sunday Times, April 22, 1990, p. 1

[168] The author is aware of reports that Czech chemical detection units found two traces of Sarin chemical weapons and one trace of Mustard Gas, and that a solider entering an Iraqi bunker may have had exposure to a chemical agent. The evidence supporting any use of chemical weapons, and and link to the "Gulf War Syndrome" is so tenuous, however, that the author believes this statement is correct. For saummary reporting on an issue that involves a wide range of technical studies and testimony, see Arms Control Today, December, 1993, p. 20; Navy Times, July 25, 1994, p. 25; Chemical and Engineering News, July 11, 1994, p. 26; and the excellent series by David Brown on the Gulf War syndrome in the Washington Post, July 24 and July 25, 1994.

[169] The author was present during several of these searches in headquarters in Iraq and Kuwait. Such materials were widely distributed.

[170] For historical background see Task Force on Terrorism and Unconventional Warfare, Chemical Weapons in The Third World: 2. Iraq's Expanding Chemical Arsenal, House Republican Research Committee, US House of Representatives, May 29, 1990, p. 8; Anthony H. Cordesman, Lessons of Modern Wars -- Volume II: The Iran-Iraq War, Boulder, Westview, 1990, pp. 510-512; W. Seth Carus, The Genie Unleashed: Iraq's Chemical and Biological Weapons Production, Washington, Washington Institute Policy Papers, No. 14., 1989, pp. 11-17.

[171] Seth Carus, The Genie Unleashed: Iraq's Chemical and Biological Weapons Production, Washington, Washington Institute Policy Papers, No. 14., 1989, p. 11.

[172] The persistence of chemical agents is dependent on wind and temperature, and whether they are disperse as liquids or aerosols. Gases tend to disperse quickly in very hot weather and to persist far longer in cold weather. It is important to note that gases that may disperse in minutes under some conditions take days to disperse under others, and that persistent gases that last days or weeks in hot weather can last up to three times longer in cold weather.

[173] For general sources for this analysis see unpublished "Statement of the Honorable William H. Webster, Director, Central Intelligence Agency, Before the Committee on Governmental Affairs, Hearings on Global Spread of Chemical and Biological Weapons", February 9, 1989; Task Force on Terrorism and Unconventional Warfare, Chemical Weapons in The Third World: 2. Iraq's Expanding Chemical Arsenal, House Republican Research Committee, US House of Representatives, May 29, 1990, p. 8; Anthony H.

Cordesman, Lessons of Modern Wars -- Volume II: The Iran-Iraq War, Boulder, Westview, 1990; W. Seth Carus, The Genie Unleashed: Iraq's Chemical and Biological Weapons Production, Washington, Washington Institute Policy Papers, No. 14., 1989.

[174] Christian Science Monitor, January 23, 1992, p. 1; Terry J. Gander, "Iraq -- the Chemical Arsenal," Jane's Intelligence Weekly, pp. 413-415; Steven R. Bowman, "Iraqi Chemical Weapons Capabilities," Washington, Congressional Research Service 93-292F, February 24, 1993.

[175] Nerve gases are more complex to manufacture than mustard gas. There are more ways to manufacture nerve gases than mustard gas, and many types of chemicals that can be used, but sales of most of these chemicals -- such as pinacolyl alcohol, potassium fluoride, phosphorous oxychloride, phosphorous trichloride, and trimethyl phosphite -- are easy to track and many have only limited commercial applications. Task Force on Terrorism and Unconventional Warfare, Chemical Weapons in The Third World: 2. Iraq's Expanding Chemical Arsenal, House Republican Research Committee, US House of Representatives, May 29, 1990, p. 8; Anthony H. Cordesman, Lessons of Modern Wars -- Volume II: The Iran-Iraq War, Boulder, Westview, 1990, pp. 510-512; W. Seth Carus, The Genie Unleashed: Iraq's Chemical and Biological Weapons Production, Washington, Washington Institute Policy Papers, No. 14., 1989, pp. 11-17.

[176] Terry J. Gander, "Iraq -- the Chemical Arsenal," Jane's Intelligence Weekly, pp. 413-415; Steven R. Bowman, "Iraqi Chemical Weapons Capabilities," Washington, Congressional Research Service 93-292F, February 24, 1993; Peter Dunn, "The Chemical War: Journey to Iran, NBC Defense & Technology International, pp. 28-37; Seth Carus, The Genie Unleashed: Iraq's Chemical and Biological Weapons Production, Washington, Washington Institute Policy Papers, No. 14., 1989, pp. 22-23; Foreign Report, March 31, 1988, p. 12; and "Iran Keep Chemical Options Open", pp. 12-14. Jane's Defense Weekly, January 9, 1988, p. 3; February 27, 1988, p. 336. The Austrian firms seems to have included Neuberger Holz und Kunstoffindustrie and Lenhardt Metallbau under Dachdecker. Five West German firms seem to have been involved, including WTB (Walter Thosti Boswau), Infraplan, and Karl Kolb.

[177] Seth Carus, "Chemical Weapons in the Middle East," Policy Focus, Number Nine, Washington Institute for Near East Policy, December, 1988, p. 4; "Iraq's Scare Tactic," Newsweek, August 2, 1982; Washington Post, April 5, 1988, p. A-1. Task Force on Terrorism and Unconventional Warfare, Chemical Weapons in The Third World: 2. Iraq's Expanding Chemical Arsenal, House Republican Research Committee, US House of Representatives, May 29, 1990, p. 8.

[178] Task Force on Terrorism and Unconventional Warfare, Chemical Weapons in The Third World: 2. Iraq's Expanding Chemical Arsenal, House Republican Research Committee, US House of Representatives, May 29, 1990, p. 8; Anthony H. Cordesman, Lessons of Modern Wars -- Volume II: The Iran-Iraq War, Boulder, Westview, 1990, pp. 510-512; W. Seth Carus, The Genie Unleashed: Iraq's Chemical and Biological Weapons Production, Washington, Washington Institute Policy Papers, No. 14., 1989, pp. 11-17.

[179] It takes 0.45 tons of ethylene oxide to make 1.0 tons of Thiodiglycol. Carus, p. 15.

[180] Task Force on Terrorism and Unconventional Warfare, Chemical Weapons in The Third World: 2. Iraq's Expanding Chemical Arsenal, House Republican Research Committee, US House of Representatives, May 29, 1990, pp. 9-10.

[181] "Iraq's Scare Tactic," Newsweek, August 2, 1982; Washington Post, April 5, 1988, p. A-1.

[182] "Iraq's Scare Tactic," Newsweek, August 2, 1982; Washington Post, April 5, 1988, p. A-1; Seth Carus, The Genie Unleashed: Iraq's Chemical and Biological Weapons Production, Washington, Washington Institute Policy Papers, No. 14., 1989, pp. 7-9; Task Force on Terrorism and Unconventional Warfare, Chemical Weapons in The Third World: 2. Iraq's Expanding Chemical Arsenal, House Republican Research Committee, US House of Representatives, May 29, 1990, p. 9; Department of Defense, Conduct of the Persian Gulf War: Final Report, Department of Defense, April, 1992, p. 18.

[183] Dick Palowski, Changes in Threat Air Combat Doctrine and Force Structure, 24th Edition, Fort Worth, General Dynamics DWIC-01, February, 1992, p. II-325.

[184] The Independent, July 28, 1991, p. 2. Peter Dunn, "The Chemical War: Journey to Iran", NBC Defense & Technology International, pp. 28-37; "Iran Keeps Chemical Options Open", pp. 12-14; Seth Carus, The Genie Unleashed: Iraq's Chemical and Biological Weapons Production, Washington, Washington Institute Policy Papers, No. 14., 1989, p. 22; Dick Palowski, Changes in Threat Air Combat Doctrine and Force Structure, 24th Edition, Fort Worth, General Dynamics DWIC-01, February, 1992, pp. II-375.

[185] The priority Iraq gave to chemical and biological weapons is illustrated by the fact that Hussein Kamil -- Saddam Hussein's son-in-law and cousin -- headed the Ministry of Industry and Military Industries during most of this period. The Ministry of Industry and Military Industries is the branch of the Iraqi government which is responsible for the production of chemical and biological weapons. Michael Eisenstadt, "The Sword of the Arabs:" Iraq's Strategic Weapons, Washington, Washington Institute for Near East Policy, Policy Paper 21, September, 1990, p. 7. W. Seth Carus, "Chemical Weapons in the Middle East," Policy Focus, Number Nine, Washington Institute for Near East Policy, December, 1988, p. 4; "Iraq's Scare Tactic," Newsweek, August 2, 1982; Washington Post, April 5, 1988, p. A-1; Dick Palowski, Changes in Threat Air Combat Doctrine and Force Structure, 24th Edition, Fort Worth, General Dynamics DWIC-01, February, 1992, pp. II-325 and II-334; Jane's Soviet Intelligence Review, June, 1989, p. 256; Foreign Report, March 31, 1988, p. 1.

[186] Washington Post, April 30, 1993, p. A-45; Christian Science Monitor, January 25, 1993, p. 18; Financial Times, April 2, 1992, p. 3, April 30, 1993, p. 5; The Economist, February 6, 1993, pp. 49-50; New York Times, June 26 ,1993, p. A-19; Los Angeles Times, July 20, 1992, p. C2; Chemical and Engineering News, May 3, 1993, pp. 8-9.

[187] New York Times, April 3, 1990, p. 1

[188] The UN did not find signs of the use of chemical weapons during its inspection of the marsh areas in November, 1993, but referred soil samples to experts. Washington Post, November 24, 1993, p. A-12; Jane's Defense Weekly, January 9, 1988, and January 28, 1989; Der Spiegel, January 23, 1989; Task Force on

Terrorism and Unconventional Warfare, Chemical Weapons in The Third World: 2. Iraq's Expanding Chemical Arsenal, House Republican Research Committee, US House of Representatives, May 29, 1990, p. 10; Baghdad Domestic Service, April 2, 1990.

[189] Michael Eisenstadt, "The Sword of the Arabs:" Iraq's Strategic Weapons, Washington, Washington Institute for Near East Policy, Policy Paper 21, September, 1990, p. 7. W. Seth Carus, "Chemical Weapons in the Middle East," Policy Focus, Number Nine, Washington Institute for Near East Policy, December, 1988, p. 4; "Iraq's Scare Tactic," Newsweek, August 2, 1982; Washington Post, April 5, 1988, p. A-1; Dick Palowski, Changes in Threat Air Combat Doctrine and Force Structure, 24th Edition, Fort Worth, General Dynamics DWIC-01, February, 1992, pp. II-325 and II-334; Jane's Soviet Intelligence Review, June, 1989, p. 256; Foreign Report, March 31, 1988, p. 1; New York Times, November 12, 1991.

[190] The author visited many Iraqi positions the week after the war with senior Saudi officers. At several field headquarters positions, we found orders and instructions for the use of chemical weapons.

[191] Dick Palowski, Changes in Threat Air Combat Doctrine and Force Structure, 24th Edition, Fort Worth, General Dynamics DWIC-01, February, 1992, pp. II-326 to II-327.

[192] Eliot Cohen, ed., Gulf War Air Power Survey, Volume II, Part II, p. 324.

[193] Eliot Cohen, ed., Gulf War Air Power Survey, Volume II, Part II, p. 322-326.

[194] Defense News, June 27, 1994, p. 10.

[195] Terry J. Gander, "Iraq -- the Chemical Arsenal," Jane's Intelligence Weekly, pp. 413-415; Steven R. Bowman, "Iraqi Chemical Weapons Capabilities," Washington, Congressional Research Service 93-292F, February 24, 1993.

[196] Washington Post, July 26, 1991, p. A-1.

[197] New York Times, July 31, 1991, p. A-1, November 12, 1991, p. A-3; Christian Science Monitor, January 23, 1992, p. 1; Associate Press, December 12, 1991, PM cycle. Terry J. Gander, "Iraq -- the Chemical Arsenal," Jane's Intelligence Weekly, pp. 413-415; Steven R. Bowman, "Iraqi Chemical Weapons Capabilities," Washington, Congressional Research Service 93-292F, February 24, 1993.

[198] Rick Atkinson, Crusade, pp. 223-224.

[199] Terry J. Gander, "Iraq -- the Chemical Arsenal," Jane's Intelligence Weekly, pp. 413-415

[200] Baltimore Sun, November 3, 1991, p. 16A; New York Times, November 12, 1991, p. A-3; Jane's Defense Weekly, December 14, 1991, pp. 1144-1145; Associate Press, December 12, 1991, PM cycle; London Times, March 4, 1992, p. 10; Christian Science Monitor, January 23, 1992, p. 1.

[201] For a good overview of the options, see Norman Cigar, "Chemical Weapons and the Gulf War, the Dog That Did Not Bark," Studies in Conflict and Terrorism, Volume 15, 1992, pp. 145-152.

[202] There are some indications a chemical device may have gone off in Iraq. Czech anti-chemical warfare units in the Gulf claim to have detected traces of small amounts of Sarin. This has led to speculation that the Iraqis may have had a warhead or bomb explode accidentally. Washington Post, November 11, 1993; Briefing by

Secretary of Defense Les Aspin and Undersecretary of Defense for Acquisition and Technology, John M. Deutch, November 10, 1993; Arms Control Today, December, 1993, p. 20; Navy Times, July 25, 1994, p. 25; Chemical and Engineering News, July 11, 1994, p. 26; Washington Post, July 24 and July 25, 1994.

203 See Department of Defense, Conduct of the Persian Gulf War: Final Report, Department of Defense, April, 1992, pp. 207 and Lt. Colonel Jeffery D. McCausland, "How Iraq's CBW Threat Affected Coalition Operations," Defense and Foreign Affairs, September, 1992, pp. 12-16; General Schwarzkopf's Press Conference of February 27, 1991 in New York Times, February 28, 1991, p. A-8.

204 For a good detailed analysis of this issue, see Thomas L. McNaugher, "Ballistic Missiles and Chemical Weapons: The Legacy of the Iran-Iraq War," International Security, 15:2, pp. 5-34.

205 Washington Post, November 11, 1993.

206 New York Times, November 12, 1991, p. A-3; Christian Science Monitor, January 23, 1992, p. 1.

207 Department of Defense, Conduct of the Persian Gulf War: Final Report, Department of Defense, April, 1992, p. 207

208 New York Times, November 12, 1991, p. A3; Christian Science Monitor, January 23, 1992, p. 1; Jane's Defense Weekly, December 14, 1991, pp. 1144-1145; Associate Press, December 12, 1991, PM cycle.

209 Department of Defense, Conduct of the Persian Gulf War: Final Report, Department of Defense, April, 1992, pp. 16-18; "Ambassador Rolf Ekrus, "Unearthing Iraq's Arsenal," Arms Control Today, April 1992, pp. 6-9; Christian Science Monitor, January 23, 1992, p. 1; The Atlanta Constitution, January 16, 1992, p. 1.; Jane's Defense Weekly, December 14, 1991, pp. 1144-1145; Associate Press, December 12, 1991, PM cycle. The UN found nearly 100 metal working machines for chemical weapons at the plant during a raid on November 20, 1991;

210 The technical content of this discussion is adapted in part from the author's discussion of the technical aspects of such weapons in After the Storm: The Changing Military Balance in the Middle East, Boulder, Westview, 1993; working material on biological weapons prepared for the United Nations, and from Office of Technology Assessment, Proliferation of Weapons of Mass Destruction: Assessing the Risks, United States Congress OTA-ISC-559, Washington, DC, August, 1993; Kenneth R. Timmerman, Weapons of Mass Destruction: The Cases of Iran, Syria, and Libya, Simon Wiesenthal Center, Los Angeles, August, 1992; Dr. Robert A, Nagler, Ballistic Missile Proliferation: An Emerging Threat; Systems Planning Corporation, Arlington, 1992; and translations of unclassified documents on proliferation by the Russian Foreign Intelligence Bureau provide to the author by the staff of the Government Operations Committee of the US Senate.

211 Many sources classify mycotoxins as chemical poisons. Unfortunately, mycotoxins have become one of those weapons that are popular with journalists or propagandists seeking to sensationally a given conflict, and countries are often accused of using mycotoxins in cases where ambiguous symptoms are present. Iran has also been accused of producing and using mycotoxins.

[212] Task Force on Terrorism and Unconventional Warfare, Chemical Weapons in The Third World: 2. Iraq's Expanding Chemical Arsenal, House Republican Research Committee, US House of Representatives, May 29, 1990, p. 12; Wiener Zeitung, June 25, 1989.

[213] Seth Carus, The Genie Unleashed: Iraq's Chemical and Biological Weapons Production, Washington, Washington Institute Policy Papers, No. 14., 1989, pp. 29-35.

[214] For a range of sources on Iraqi capabilities, see New York Times, December 30, 1992; Department of Defense, Conduct of the Persian Gulf War: Final Report, Department of Defense, April, 1992, pp. 16-19; Andrew Terril, "Chemical Weapons in the Gulf War," Strategic Review, Spring, 1986; Washington Times, January 19, 1989, p. A-6; January 27, 189, p. A-2; Baltimore Sun, August 19, 1990, p. 5E; Leonard Spector, Proliferation Today, New York, Vintage Books, 1984; Arms Control Today, April, 1992, pp. 7-8.

[215] Department of Defense, Conduct of the Persian Gulf War: Final Report, Department of Defense, April, 1992, p. 18; Washington Times, January 19, 1989, p. A-8.

[216] Baltimore Sun, August 19, 1990, p. 5-E; Government of Canada, "Collateral Analysis and Verification of Biological and Toxin Research in Iraq," October, 1991.

[217] Government of Canada, "Collateral Analysis and Verification of Biological and Toxin Research in Iraq," October, 1991.

[218] Middle East Economic Digest, June 27, 1987, p. 16, August 29, 1987, p. 10; June 10, 1988, p. 9, June 24, 1988, p. 9, October 14, 1988, p. 20, February 10, 1989, p. 15; Seth Carus, The Genie Unleashed: Iraq's Chemical and Biological Weapons Production, Washington, Washington Institute Policy Papers, No. 14., 1989, pp. 33-35; Gulf War Air Power Survey, Volume IV, Part I, p. 327.

[219] FBIS, Daily Report, Western Europe, January 23, 1989, p. 11, January 25, 1989, p. 8, and February 6, 1989, p. 9; Der Spiegel, January 23, 1989, pp. 16-27.

[220] FBIS, Daily Report, Western Europe, January 30, 1989, pp. 9-10, Wall Street Journal, February 1, 1989, p. A-11.

[221] Listed in Senate Foreign Relations Committee, Republican Staff, "Weapons Sales to Iraq," Working Paper, October 17, 1990.

[222] Government of Canada, "Collateral Analysis and Verification of Biological and Toxin Research in Iraq," October, 1991.

[223] Jane's Defense Weekly, September 14, 1991, p. 471.

[224] Washington Post, August 15, 1991, p. A-31; Jane's Defense Weekly, September 14, 1991, p. 471.

[225] For a good update on biological weapons technology and defensive countermeasures, see Kathleen C. Bailey, editor, Directors Series on Proliferation, No. 4, Lawrence Livermore National Laboratory, UCRL-LR-114070-4, May 24, 1994.

[226] Eliot Cohen, ed., Gulf War Air Power Survey, Volume II, Part II,, p. 327.

[227] Department of Defense, Conduct of the Persian Gulf War: Final Report, Department of Defense, April,

1992, pp. 207.

[228] Department of Defense, Conduct of the Persian Gulf War: Final Report, Department of Defense, April, 1992, pp. 207.

[229] Eliot Cohen, ed., Gulf War Air Power Survey, Volume II, Part II,, p. 327.

[230] The Atlanta Constitution, January 16, 1992, p. 1.

[231] The technical content of this discussion is adapted in part from the author's discussion of the technical aspects of such weapons in After the Storm: The Changing Military Balance in the Middle East, Boulder, Westview, 1993; working material on biological weapons prepared for the United Nations, and from Office of Technology Assessment, Proliferation of Weapons of Mass Destruction: Assessing the Risks, United States Congress OTA-ISC-559, Washington, DC., August, 1993; Kenneth R. Timmerman, Weapons of Mass Destruction: The Cases of Iran, Syria, and Libya, Simon Wiesenthal Center, Los Angeles, August, 1992; Dr. Robert A, Nagler, Ballistic Missile Proliferation: An Emerging Threat; Systems Planning Corporation, Arlington, 1992; and translations of unclassified documents on proliferation by the Russian Foreign Intelligence Bureau provide to the author by the staff of the Government Operations Committee of the US Senate.

[232] For a different national perspective, see Gerald M. Steinberg, "Israeli Responses to the Threat of Chemical Warfare," Armed Forces & Society, Fall, 1993, pp. 85-96.

[233] For another view of this issue, see Bruce W. Watson, et al, Military Lessons of the Gulf War, London, Greenhill, 1991, pp. 74-75.

[234] Department of Defense, Conduct of the Persian Gulf War: Final Report, Department of Defense, April, 1992, pp. 18.

[235] Department of Defense, Conduct of the Persian Gulf War: Final Report, Department of Defense, April, 1992, pp. 206-207. For some of the reasons and problems in targeting and battle management, see Rick Atkinson, Crusade, pp. 295-296.

[236] The $10 billion dollar figure is a UN staff estimate. See New York Times, October 14, 1991, p. A-6.

[237] IAEA comments on CRS-93 323F, Fax by IAEA UNSC 687 Action Team, June 23, 1993.

[238] Sources for this list and the following discussion include: IAEA Comments on CRS 93-323F, June 23, 1993, fax by UNSC 687 Action Team; J. Davis and D. Kay, "Iraq's Secret Nuclear Weapons Program," Physics Today, July, 1992; D. Albright and M. Hibbs, "Iraq's Shop Till You Drop Nuclear Program," Bulletin of the Atomic Scientists, April, 1992; D. Albright and M. Hibbs, "Iraq's Nuclear Hide and Seek," Bulletin of the Atomic Scientists, September, 1991; D. Albright and M. Hibbs, "Iraq's Quest for the Nuclear Grail: What Can We Learn?," Arms Control Today, July/August, 1992, pp. 7-8; Washington Post, October 13, 1991, p. A-1; Newsweek, October 7, 1991, pp. 28-33; US News and World Report, November 25, 1991, pp. 34-40; Chicago Tribune, October 6, 1991, p. I-28; United Nations Security Council, Report on the First and Second IAEA Inspection in Iraq Under Security Council Resolution 687, 15 July, 1991, New York, United Nations,

S/22788 (English); Report on the Third IAEA Inspection in Iraq Under Security Council Resolution 687, 25 July, 1991, New York, United Nations, S/23283 (English); Report on the Fourth IAEA Inspection in Iraq Under Security Council Resolution 687, 28 August, 1991, New York, United Nations, S/22986 (English); Report on the Fifth IAEA Inspection in Iraq Under Security Council Resolution 687, 4 October, 1991, New York, United Nations, S/23112 (English); Report on the Seventh IAEA Inspection in Iraq Under Security Council Resolution 687, 6 October, 1991, New York, United Nations, S/23122 (English); Report on the Seventh IAEA Inspection in Iraq Under Security Council Resolution 687, 14 November, 1991, New York, United Nations, S/232215 (English); Report on the Eighth IAEA Inspection in Iraq Under Security Council Resolution 687, 11-18 November, 1991, New York, United Nations, S/23283 (English); Report on the Ninth IAEA Inspection in Iraq Under Security Council Resolution 687, 30 January 1992, New York, United Nations, S/23505 (English); Milhollin, Gary, "The Iraqi Bomb," New Yorker, February p.47-55. David Albright and Mark Hibbs, "Supplier-spotting, Bulletin of the Atomic Scientists, January/February, 1993, pp. 8-9; Tim Ripley, "Iraq's Nuclear Weapons Program," Jane's Intelligence Review, December, 1992, pp. 554-558. Lawrence Scheinman, "Lessons From Post-War Iraq for the International Full-Scope Safeguard Regime, Arms Control Today, April, 1993, pp. 3-6; Hans Blix, "Verification of Nuclear Nonproliferation: The Lesson of Iraq," The Washington Quarterly, Autumn, 1992, pp. 57.-65; Terry J. Gander, "Iraq -- The Chemical Arsenal," Jane's Intelligence Review, September 1992, pp. 413-415; Maurizio Ziffereo, "The IAEA: Neutralizing Iraq's Nuclear Weapons Potential," Arms Control Today, April, 1993, pp. 7-10; Alan George, "Nuclear complicity," The Middle East, March, 1993, pp. 12-13 and "Iraq: Weapons Sanctions Aren't Working," The Middle East, September, 1993, pp. 14-15; Tim Ripley, "Iraq's Nuclear Weapons Program," December, 1992, PP. 544-588; Peter D. Zimmerman, "Iraq's Nuclear Achievements: Components, Sources, and Stature," Congressional Research Service 93-323F, February 18, 1993.

[239] United Nations Security Council, Report on the Eighth IAEA Inspection in Iraq Under Security Council Resolution 687, 11-18 November, 1991, New York, United Nations, S/23283 (English), p. 14.

[240] US News and World Report, November 25, 1991, p. 36.

[241] United Nations Security Council, Report on the Eighth IAEA Inspection in Iraq Under Security Council Resolution 687, 11-18 November, 1991, New York, United Nations, S/23283 (English), p. 14.

[242] James Bruce, "Iraq and Iran: Running the Nuclear Technology Race," Jane's Defense Weekly, December 5, 1988, p. 1307; New York Times, July 10, 1992.

[243] Washington Times, August 29, 1990, p. 8; South, July 1987, pp. 99-100; Stern, April 6, 1989, pp. 214-217; Der Spiegel, December 18-25, 1989, pp. 93-94; Michael Eisenstadt, "The Sword of the Arabs:" Iraq's Strategic Weapons, Washington, Washington Institute for Near East Policy, Policy Paper 21, September, 1990, pp. 11-13.

[244] Nuclear Fuel, August 5, 1991, Vol. 16, No. 16, p. 14.

[245] It takes 15 to 25 kilograms to make one relatively simple nuclear weapon. More advanced weapons take

substantially less. The IAEA did, however, certify on May 7, 1990, that all such material was still accounted for. Source: IAEA Office, United Nations, New York, New York.

[246] New York Times, February 13, 1992, p. A-16; Zachary SA. Davis and Warren H. Donnelly, "Iraq and Nuclear Weapons," Congressional Research Service, IB90113, February 13, 1992, p. 3; David Albright and Mark Hibbs, "News that the front page missed, " Bulletin of the Atomic Scientists, October, 1991, pp. 7-9; Peter D. Zimmerman, "Iraq's Nuclear Achievements: Components, Sources, and Stature," Congressional Research Service, 93-323F, February 18, 1993.

[247] US News and World Report, Vol. 112, January 20, 1992, p. 45; London Financial Times, January 15, 1992, p. 1.

[248]Maximum ultimate design capability was 2,000 centrifuges per year. Washington Post, May 5, 1989; Rochester Democrat and Chronicle, March 28, 1989; New York Times, January 15, 1992; David Albright and Mark Hibbs, "News that the front page missed, " Bulletin of the Atomic Scientists, October, 1991, pp. 7-9; Report on the Seventh IAEA Inspection in Iraq Under Security Council Resolution 687, 14 November, 1991, New York, United Nations, S/232215 (English), p. 19; David Albright and Mark Hibbs, "Iraq's Shop-Till-You Drop Nuclear Program," Bulletin of the Atomic Scientists, April 1992, pp. 27-37.

[249] Gary Milhollin, "Building Saddam Hussein's Bomb," New York Times, March 8, 1992, pp. 30-31.

[250] H&H was headed by Walter Busse, a former employee of MAN Technologies Ltd. which had built the uranium centrifuge assembly plant at Gronau in West Germany for URENCO. Washington Post, June 4, 1989; Der Spiegel, December 18, 1989; FBIS-Western Europe, December 20, 1989; Nucleonics Week, May 4, 1987, p. 1; Wall Street Journal, October 29, 1991, p. 24.

[251] Wall Street Journal, October 7, 1991, p. A-10.

[252] Michael Eisenstadt, "The Sword of the Arabs:" Iraq's Strategic Weapons, Washington, Washington Institute for Near East Policy, Policy Paper 21, September, 1990, pp. 11-13; Rochester Democrat and Chronicle, March 28, 1988, pp. 1A and 10A; Washington Post, May 5, 1989, p. A-24.

[253] The Middle East, May, 1990, pp. 11-14.

[254] H&H was headed by Walter Busse, a former employee of MAN Technologies Ltd. which had built the uranium centrifuge assembly plant at Gronau in West Germany for URENCO. It seems to have provided machinery for the production of gas ultracentrifuges. Washington Post, June 4, Los Angeles Times, December 12, 1991, A-9; Associated Press, December 11, 1991 AM cycle. Other firms named at this time included Schenk Werzberg and Machinebau, 1989; Der Spiegel, December 18, 1989; FBIS-Western Europe, December 20, 1989; Nucleonics Week, May 4, 1987, p. 1; Gary Milhollin, "Building Saddam Hussein's Bomb," New York Times, March 8, 1992, pp. 30-31.

[255] New York Times, January 15, 1992, p. A-1.

[256] IAEA comments on CRS-93 323F, Fax by IAEA UNSC 687 Action Team, June 23, 1993.

[257] Michael Eisenstadt, "The Sword of the Arabs:" Iraq's Strategic Weapons, Washington, Washington

Institute for Near East Policy, Policy Paper 21, September, 1990, p. 15.

[258] Washington Post, October 5, 1991, p. A-1; Wall Street Journal, October 29, 1991, p. 24.

[259] Washington Post, November 2, 1991, p. C-1

[260] New York Times, January 15, 1992, p. A-1; US News and World Report, Vol. 112, January 20, 1992, p. 45; Star Tribune, November 22, 1991, p. 22A, Christian Science Monitor, October 23, 1991, p. 9.

[261] US News and World Report, November 25, 1991, p. 36. Vol. 112, January 20, 1992, p. 45; United Nations Security Council, Report on the Eighth IAEA Inspection in Iraq Under Security Council Resolution 687, 11-18 November, 1991, New York, United Nations, S/23283 (English); David Albright and Mark Hibbs, "Iraq's Shop-Till-You Drop Nuclear Program," Bulletin of the Atomic Scientists, April 1992, pp. 27-37.

[262] IAEA comments on CRS-93 323F, Fax by IAEA UNSC 687 Action Team, June 23, 1993.

[263] Zachary SA. Davis and Warren H. Donnelly, "Iraq and Nuclear Weapons," Congressional Research Service, IB90113, February 13, 1992, p. 3; David Albright and Mark Hibbs, "Iraq and the Bomb: Were They Even Close?, Bulletin of Atomic Scientists, March, 1991, pp. 16-25; David Albright and Mark Hibbs, "Its all over at Al Atheer," Bulletin of Atomic Scientists, June, 1992, pp. 8-10; US Experts Divided on Whether Iraqi Calutrons Procure U-235," Nuclear Fuel, June 24, 1991, pp. 3-4.

[264] This analysis draws heavily on David Albright and Mark Hibbs, "Iraq and the Bomb: Were They Even Close?, Bulletin of Atomic Scientists, March, 1991, pp. 16-25; US Experts Divided on Whether Iraqi Calutrons Procure U-235," Nuclear Fuel, June 24, 1991, pp. 3-4. IAEA comments on CRS-93 323F, Fax by IAEA UNSC 687 Action Team, June 23, 1993.

[265] Iraq made this admission to the UN on October 21, 1991. New York Times, October 14, 1991, p. A6, October 20, 1991, IV-5; United Nations Security Council, Report on the Eighth IAEA Inspection in Iraq Under Security Council Resolution 687, 11-18 November, 1991, New York, United Nations, S/23283 (English), p. 9.

[266] Los Angeles Times, December 12, 1991, p. A-9.

[267] A full description of activities is not included because of their value in nuclear weapons design. United Nations Security Council, Report on the Sixth IAEA Inspection in Iraq Under Security Council Resolution 687, 8 October, 1991, New York, United Nations, S/23122 (English).

[268] Washington Post, October 5, 1991, p. A-1.

[269] Gary Milhollin, "Building Saddam Hussein's Bomb," New York Times, March 8, 1992, pp. 30-31.

[270] Many of these details are taken from Peter D. Zimmerman, Iraq's Nuclear Achievements: Components, Sources, and Stature, Washington, Congressional Research Service, 93-323F, February 18, 1993. Also see J. Carson Mark, "Some Remarks on Iraq's Possible Nuclear Weapon Capability in Light of Some of the Known Facts Concerning Nuclear Weapons," Nuclear Control Institute, Washington, May 16, 1991.

[271] The Middle East, May, 1990, pp. 11-14.

[272] US News and World Report, November 25, 1991, p. 36; United Nations Security Council, Report on the

Eighth IAEA Inspection in Iraq Under Security Council Resolution 687, 11-18 November, 1991, New York, United Nations, S/23283 (English), p. 29.

[273] The "sting" operation is a good example of what happens when a company that is concerned with proliferation takes immediate action to contact the officials in the country involved. A US Company called CSI Technologies of San Marcos, California, immediately contacted US Customs officials when it was contacted by Euromac, the Iraqi front organization, located in Thames Ditton, near London. US officials contacted British officials, and they worked together to set up a series of meetings, some of which were televised, and to make the intercept and arrests at Heathrow Airport. Ironically, Euromac was registered as a "general grocers and provision merchant". It is also unclear that the Iraqi fully understood what they were ordering. Maxwell Laboratories of San Diego had been delivering other types of capacitors to Iraq, and had delivered 518 slow speed capacitors to Iraq. Iraq then order 185 high speed capacitors. Maxwell Laboratories notified Customs, and halted the shipment at Customs' request. The new type of capacitor,, however, was still unsuitable for nuclear weapons. Andrew T. Parasiliti, "Iraq, Nuclear Weapons, and the Middle East", The Middle East Institute, December 14, 1989, pp. 4-5; Mideast Markets, Vol. 16, no. 8, April 17, 1989, p. 15 and vol. 16, no. 9, May 1, 1989, p. 12; Washington Post, March 31, 1989, p. A-1; Los Angeles Times, March 30, 1990; Washington Post, March 31, 1990, p. 2.

[274] The core of a nuclear bomb consists of fissile material, a layer of outer explosives, and a firing circuit connected to all parts of the out high explosive cover to detonate all of it at exactly the same moment and achieve maximum compression at the precise instant high energy neutrons are being injected into the compressed fissile core. Washington Times, March 28, 29, 30, 1990; Washington Post, March 28, 29, 30, 1990; New York Times, March 28, 29, 30, 1990;

[275] United Nations Security Council, Report on the Eighth IAEA Inspection in Iraq Under Security Council Resolution 687, 11-18 November, 1991, New York, United Nations, S/23283 (English). pp. 14-15, 29; Gary Milhollin, "Building Saddam Hussein's Bomb," New York Times, March 8, 1992, pp. 30-31; Report on the Seventh IAEA Inspection in Iraq Under Security Council Resolution 687, 14 November, 1991, New York, United Nations, S/232215 (English), p. 30.

[276] US News and World Report, November 25, 1991, p. 36. This same article named a number of possible US supplies, including Honeywell (computers), Canberra Industries, Inc. (computer equipment to measure neutrons and for design specifications, Carl Zeiss (computer equipment to process photographic data), Databit, inc. (computer data transmission and circuit switches), Forney International (computer equipment for power stations), Hewellet-Packard (optical fiber cables, computers, frequency synthesizers, precision electronic and photo equipment), Perkin-Elmer (computers, precision electronic, and photo equipment, Sackman Associates (computers, electronic assemblies, and photo equipment), and Westinghouse Electric (computer hardware and software for the Iraqi electric system). Many of these supplies almost certainly had little or nothing to do with the Iraqi nuclear effort.

[277] Zachary S. Davis and Warren H. Donnelly, "Iraq and Nuclear Weapons," Congressional Research Service, IB90113, February 13, 1992, p. 4; Washington Post, October 9, 1991, p. A-17.

[278] For a good overview, see David Albright and Mark Hibbs, "Iraq's Bomb: Blueprints and Artifacts," Scientific American, January/February, 1992, pp. 30-40.

[279]Report to the UN Security Council on October 8, 1991; USA Today, October 10, 1991, p. 6.

[280] Gary Milhollin, "Building Saddam Hussein's Bomb," New York Times, March 8, 1992, pp. 30-31.

[281] New York Times, May 20, 1992; David Albright and Mark Hibbs, "Iraq's Bomb: Blueprints and Artifacts," Scientific American, January/February, 1992, pp. 30-40..

[282] Gary Milhollin, "Building Saddam Hussein's Bomb," New York Times, March 8, 1992, pp. 30-31.

[283] The problem of height of burst is critical because it determines the fall out effects of a weapon, and the relative importance of blast, radiation, and thermal energy affecting a given target. Fusing is not necessarily different from the fusing needed for ordinary bombs, but the fusing on ordinary bombs often fails to function properly.

[284] Eliot Cohen, ed. , Gulf War Air Power Survey, Volume II, Part II, pp. 327-328.

[285] Eliot Cohen, ed. , Gulf War Air Power Survey, Volume II, Part II, pp. 330-331.

[286] Eliot Cohen, ed. , Gulf War Air Power Survey, Volume II, Part II, pp. 327-328.

[287] Arms Control Today, April 1993, p. 29.

[288] For very different views, see Peter D. Zimmerman, Iraq's Nuclear Achievements: Components, Sources, and Stature, Washington, Congressional Research Service, 93-323F, February 18, 1993; Gary Milhollin, "The Iraqi Bomb," New Yorker, February 1, 1993, pp. 47-55 and Diana Edensword and Gary Milhollin, "Iraq's Bomb - an Update," New York Times, April 26, 1993, p. A-17.

[289] See Kenneth Katzman, "Iraqi Compliance with Cease-Fire Agreements, Congressional Research Service, IB92117, March 25, 1994; and Note by the Secretary General, S/26584, October 14, 1993; Note by the Secretary General, S/26685, November 3, 1993 - Report of IAEA monitoring effort; Note by the Secretary General, S/26684, November 5, 1993; Note by the Secretary General, S/26825, December 1, 1993; Note by the Secretary General, S/26910, December 21, 1993; Note by the Secretary General, S/1994/31, January 14, 1994; Report on the Twenty Second IAEA Inspection, 1-15 November, 1993; Note by the Secretary General, S/1994/341, March 24, 1994; and Note by the Secretary General, S/1994/355, March 25, 1994.

[290] A full post-war list has never been published. A US government list published after the Gulf War is contained in the Federal Register, Volume 56, Number 64, April 3, 1991, pp. 13584 to 13589.

[291] See Hans Blix, "Verification of Nonproliferation: The Lesson of Iraq," The Washington Quarterly, Autumn, 1992, pp. 57-65; Lawrence Scheinman, "Lessons from Post-War Iraq for the International Full-Scope Safeguards Regime," Arms Control Today, April, 1993, pp. 3-6; Maurizio Zifferero, "The IAEA: Neutralizing Iraq's Nuclear Weapons Potential," Arms Control Today, pp. 7-10; Peter D. Zimmerman, Iraq's Nuclear Achievements: Components, Sources, and Stature, Washington, Congressional Research Service 93-

323 F, February 18, 1993.

[292] For an excellent analysis of some of these risks, see Brian G. Chow and Kenneth A. Solomon, "Limiting the Spread of Weapon-Usable Fissile Materials," Santa Monica, RAND Corporation, November 17, 1993.