

Ballistic Missiles and Weapons of Mass Destruction

Steve Fetter

What Is the Threat?
What Should be Done?

Iraqi missile attacks against cities in Israel and Saudi Arabia have focused attention on the continuing proliferation of ballistic missile technology throughout the third world.¹ According to the Stockholm International Peace Research Institute, 25 countries have acquired or are trying to acquire ballistic missiles, either through purchase or indigenous production.² All but a few are developing countries, and the list encompasses some of the most volatile regions of the world. The greatest concentration is in the Middle East, where nine nations have missile programs. Missiles have also spread to other hot spots, including India and Pakistan, North and South Korea, Brazil and Argentina, Taiwan, and South Africa.

What are these missiles for, and why do countries want them? In particular, what types of warheads are emerging missile forces likely to be armed with? What capabilities will these missiles provide to their possessors, and what threats to international security will they pose? How should the United States and its allies respond to minimize these threats?

Since their invention in the 1930s, guided ballistic missiles have been used extensively in war only four times: the Germans launched over 2,000 V-2

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¹ The proliferation of ballistic missile technology is well chronicled. See, for example, Janne E. Nolan, *Trappings of Power: Ballistic Missiles in the Third World* (Washington, D.C.: Brookings, 1991); Aaron Karp, "Ballistic Missile Proliferation," in Stockholm International Peace Research Institute, *SIPRI Yearbook 1990: World Armaments and Disarmament* (Oxford: Oxford University Press, 1990); Robert D. Shuey, Warren W. Lenhart, Rodney A. Snyder, Warren H. Donnelly, James E. Mielke, and John D. Moteff, *Missile Proliferation: Survey of Emerging Missile Forces* (Washington, D.C.: Congressional Research Service, February 9, 1989); and Martin S. Navias, "Ballistic Missile Proliferation in the Middle East," *Survival*, Vol. 31, No. 3 (May/June 1989), pp. 225-239.

² Karp, "Ballistic Missile Proliferation," pp. 382-390. See Table 2 for a list of countries with missile programs.

missiles against urban British and European targets during World War II; Iraq and Iran together launched nearly 1000 missiles against each other's cities during the 1980–88 Iran-Iraq war; the Kabul government fired over 1000 Soviet-made Scud missiles against *Mujahideen* guerrillas in the Afghanistan civil war; and Iraq launched about 80 modified Scud missiles against cities in Israel and Saudi Arabia in the 1991 Persian Gulf war. Note that three of the four cases occurred in the last decade, and in all four cases the missiles were armed solely with conventional (i.e., high-explosive) warheads. Moreover, these missiles were used mainly for strategic attacks against cities, perhaps because they lacked the accuracy necessary to strike even soft military targets such as airfields.

Ballistic missiles with ranges greater than a few hundred kilometers are, however, an exceptionally inefficient vehicle for the delivery of conventional munitions. This has long been recognized by the nuclear powers, which use ballistic missiles almost exclusively for the delivery of nuclear warheads. The inefficiency of conventionally armed missiles seems to be well understood by the new missile states as well, since most of them are also actively seeking nuclear, chemical, and biological weapons. A missile armed with a Hiroshima-sized nuclear weapon is roughly 10,000 times more deadly than the same missile armed with high explosives. Fortunately, the development of nuclear weapons is expensive, easy to detect, and relatively easy to thwart with export controls. Chemical warheads, on the other hand, are far easier to acquire, and while they may be far less deadly than nuclear warheads, they could kill as many people as dozens or even hundreds of conventionally armed missiles. Even worse, biological warheads that disperse anthrax spores offer the possibility of inflicting casualties on the scale of small nuclear weapons.

As missile ranges increase, the civilian populations of U.S. allies (and eventually the United States itself) will become increasingly vulnerable to weapons of mass destruction. Responding to this threat should be a major preoccupation of the United States, just as ameliorating the Soviet nuclear threat has been a major policy goal for more than four decades. In fact, emerging missile arsenals may be an even greater menace, since the probability of inadvertent or accidental use is likely to be much higher, crisis instabilities are likely to be more severe, and several of these states are less politically stable than the Soviet Union has been.

Policy responses might include carrots (security guarantees and arms control), sticks (export controls, deterrence, or preventive war), and defenses

(missile, aircraft, and civil defenses). The United States has tried each of these in a somewhat haphazard manner, with mixed success. Security guarantees cannot be extended to every state, and arms control is often unappealing to rogue states or their neighbors. Export controls are notoriously difficult to enforce, and are undercut by Third World suppliers and by the similarity of military and peaceful activities. Preventive war can be highly effective, but the risks and costs it entails (combined with the international environment it fosters) makes it a very limited use as an instrument of national policy. Defenses are unlikely to be effective for a variety of reasons, and deterrence may not work in many situations. Nonetheless it is imperative, despite these shortcomings, that we weave these policy threads into a coherent and self-consistent fabric to protect civilians from weapons of mass destruction.

Missiles in the Middle East and Asia: Who's Got What?

To illustrate the missile capabilities that have become available to Third World countries, Table 1 gives the characteristics of missiles deployed in the Middle East and Asia. Israel has the most sophisticated missile capability, having orbited two satellites with its Shavit space launch vehicle. If the Shavit was used as a ballistic missile, it would be capable of delivering a half-tonne³ payload at intercontinental ranges.⁴ The Jericho 2, which is based on the same technology, can probably deliver at least two tonnes on any Arab country. India also has an ambitious program to develop satellite launchers and long-range ballistic missiles; its Agni missile is roughly comparable to the Jericho 2. In contrast to the indigenous Israeli and Indian development, Saudi Arabia purchased its missiles from China. The 68-tonne single-stage DF-3, which is limited to ranges of less than 3500 kilometers with a 1-tonne payload,⁵ is the largest missile deployed outside of the five nuclear powers.⁶

³ One tonne (te) = 1 metric ton = 1,000 kilograms = 2,200 pounds = 1 long ton = 1.1 short tons.

⁴ The estimates of throwweight versus range given here are the result of calculations based on the known or inferred characteristics of these missiles. For the characteristics of the Shavit, see Steve Fetter, "Israeli Ballistic Missile Capabilities," *Physics and Society*, Vol. 19, No. 3 (July 1990), pp. 3-4. I assume that the Jericho 2 is composed of the first two stages of the Shavit.

⁵ For the characteristics of the DF-3, see Zuwei Huang and Xinmin Ren, "Long March Launch Vehicle Family—Current Status and Future Development," *Space Technology*, Vol. 8, No. 4 (1988), pp. 371-375.

⁶ For comparison, the U.S. Minuteman III ICBM weighs 35 tonnes, the Trident II SLBM weighs 57 tonnes, and the MX missile weighs 88 tonnes. It should be noted the United States has struggled for nearly two decades to develop a mobile basing mode for the MX, in part because of the large size of the missile.

Table 1. Ballistic missiles deployed in Asia and the Middle East.

Missile	Country	Missile Mass (te)	Fuel/Stages ^a	Throw-weight ^b (te)	Range ^c (km)	Supplier
Scud B	Afghanistan, Egypt, Iran, Iraq, Libya, North Korea, Syria, Yemen	6	L/1	1	300	USSR
al-Abbas	Iraq	8	L/1	1	450	USSR (modified by Iraq)
DF-3	Saudi Arabia	68	L/1	2	2800	China
Jericho 1	Israel		S/2	1	500	
Jericho 2	Israel, South Africa?	≈16	S/2	2	2000	Israel?
Prithvi	India	4	L/1	1	240	
Agni	India	14	S/L/2	1	2500	

NOTES: Includes all missiles with a payload of at least 500 kilograms at a range of 300 kilometers, which is the threshold for export restrictions under the Missile Technology Control Regime.

b. "L" = liquid; "S" = solid.

c. Typical payload/range combination.

At the other end of the spectrum is the ubiquitous Soviet Scud-B missile, capable of delivering a 1-tonne payload at a range of only 300 kilometers.⁷ The Scud-B was modified by Iraq to carry a much smaller payload at ranges of up to 600 kilometers, enabling its use in attacks on Teheran, Riyadh, and Tel Aviv during the 1980–88 and 1991 Persian Gulf wars. A more extensive modification, called the al-Abbas, may be capable of delivering a half-tonne warhead at such ranges.⁸

⁷ For the characteristics of the Scud B, see Steven Zaloga, "Ballistic Missiles in the Third World: *International Defense Review*, Vol. 21 (November 1988), p. 1427.

⁸ For the characteristics of the modified Scuds, see W. Seth Carus and Joseph S. Bermudez, Jr., "Iraq's Al-Husayn Missile Programme," *Jane's Soviet Intelligence Review*, May 1990, pp. 205.

WHY BUY MISSILES?

Why use ballistic missiles rather than aircraft? After all, aircraft are reusable, more versatile, and are capable of much better accuracy than first-generation missiles. The most common answer is that it is much easier to defend against an attack by aircraft. Even though British air defenses were very good late in World War II, Britain was utterly defenseless against the V-2, which reentered the lower atmosphere at speeds in excess of Mach 3. Not until the United States deployment of the Patriot anti-tactical missile system in Saudi Arabia and Israel has a country demonstrated a capability to defend itself against attack by even short-range missiles. Although the Patriot system was apparently very effective,⁹ it was far from perfect and, in the face of U.S. air supremacy, missile attack was Iraq's only means for carrying out strategic attacks on U.S. allies.

A comparison of costs shows, furthermore, that missiles are rarely a cost-effective means for delivering conventional explosives. Although aircraft are about three times as expensive as missiles per unit takeoff or launch weight,¹⁰ aircraft can carry up to ten times more payload per unit takeoff weight to intermediate ranges.¹¹ Moreover, aircraft can be reused until they are shot down. Figure 1 shows that missiles are only cost-effective for very short ranges or if aircraft attrition rates are very high. For example, at a range of 500 kilometers, a single-stage missile is only cost-effective if aircraft attrition rates are greater than 35 percent per sortie. Even modern, solid-fuel, two-stage missiles are not cost-effective at such ranges unless aircraft attrition rates are greater than 25 percent per sortie. Attrition rates greater than 10 percent are rare, and only occur when a combatant is greatly overmatched or when targets are especially well-defended.¹²

⁹ The actual effectiveness of Patriot interceptors in destroying Scud warheads is subject to intense debate. See footnote 61.

¹⁰ Based on unit flyaway costs and maximum takeoff/launch weights of seven U.S. missiles and seven U.S. aircraft given in Thomas B. Cochran, William M. Arkin, and Milton M. Hoenig, *Nuclear Weapons Databook*, Vol. I: *U.S. Nuclear Forces and Capabilities* (Cambridge, Mass.: Ballinger, 1984).

¹¹ For example, 30–35 percent of the takeoff weight of U.S. aircraft is payload at unrefueled ranges of up to 1500 kilometers. International Institute for Strategic Studies (IISS), *The Military Balance 1988-89* (London: IISS, 1988). For comparison, the throwweight of the Scud-B missile is 17 percent of its launch weight at a range of only 300 kilometers, and the throwweight of the modified Scuds used against Teheran and Tel Aviv was less than 3 percent of the launch weight.

¹² The overall attrition rate for American aircraft in the European theatre from August 1942 to May 1945 was 2 percent per sortie, although the loss rate in a single raid on a particularly well-defended target (the Schweinfurt ball-bearing plant) reached 20 percent. Robert Futrell, *Ideas, Concepts, Doctrine: A History of Basic Thinking in the United States Air Force 1907-1964*

The loss of highly trained pilots when aircraft are shot down is undoubtedly an important reason for preferring to use missiles when attrition rates are higher than, say, ten percent. This consideration points to another possibility, however: remove the pilots. Pilotless aircraft or cruise missiles generally are not reusable,¹³ but they could be much cheaper than piloted craft. The current U.S. sea-launched cruise missile (SLCM), with a flyaway cost of about \$1.5 million and a payload of less than 500 kilograms at a range of 1,300 kilometers, is not a bargain. But with the advent of low-cost satellite navigation receivers in the near future, high accuracy will be possible without the sophisticated radar and optical digital-scene-matching technology employed in the SLCM. It should be possible to build a simple, low-flying cruise missile with the same payload and range as the SLCM for less than \$250,000.¹⁴ Even at this price, cruise missiles would not be cost-effective unless the attrition rate for piloted aircraft were very high (e.g., greater than 15 percent per sortie).¹⁵

(Maxwell Air Force Base: Air University, 1974), p. 80; R.V. Jones, *Most Secret War* (Sevenoaks, England: Coronet, 1979). The North Vietnamese inflicted attrition rates of 3 percent per sortie on U.S. B-52s over Hanoi in 1972 using Soviet SA-2 surface-to-air missiles (SAMs). During the 1973 war, Israeli A-4 aircraft suffered attrition rates of 1 to 1.5 percent from Soviet SA-6 SAMs. Even against the Soviet Union, which has the most extensive air defense network in the world, the U.S. Air Force estimated (in the mid-1970s) that its bombers would suffer attrition rates of only about 15 percent. Alton H. Quanbeck and Archie L. Wood, *Modernizing the Strategic Bomber Force: Why and How* (Washington, D.C.: Brookings, 1976), pp. 64-65.

¹³ Cruise missiles might eventually be designed to release bombs and return to landing strips, but this would result in at least a factor of two decrease in their range and would add considerably to their cost.

¹⁴ Beech Aircraft Corporation makes a turbojet-powered drone (the MQM-107) with a maximum payload of about 200 kilograms and a range of about 800 kilometers that sells for about \$160,000; a similar vehicle with a payload of 500 kilograms and range a range of 1300 kilometers could probably be built for about \$250,000 (i.e., six times less than the SLCM). Northrup and Teledyne Ryan also make unpiloted aircraft for targets and reconnaissance, although at somewhat higher prices. Teledyne can equip its drones with light-weight Global Positioning System (GPS) receivers, resulting in accuracies of about 30 meters for commercial users. Teledyne has also developed a radar altimeter that allows its drone to fly over water just 10 feet above the wave tops. By using propellers instead of turbojet engines, the cost to deliver 500 kilograms to 1300 kilometers would be less than \$100,000, but the speed would be much lower. (Based on author's communications with Beech Aircraft, Northrup, and Teledyne engineers, March 27, 1991.)

¹⁵ For example, the U.S. A-6 and F-15 can deliver 8,100 and 9,000 kilograms of payload at a distance of 1,250 and 1,440 kilometers for a flyaway cost of \$19 and \$22 million, respectively. Sixteen to 18 cruise missiles each carrying 500 kilograms would be required to deliver an equal payload, which, at \$250,000 per missile, would cost \$4 to \$4.5 million—about five times less the cost of aircraft. Therefore, ignoring the loss of pilots, attrition rates greater than 15 percent are necessary to make the cruise missiles cost-effective compared to piloted aircraft, even if the cruise missiles themselves suffer no attrition.

Apart from air defenses, there are other, perhaps more powerful incentives to buy missiles rather than aircraft. First, missile attack appears to have a greater psychological impact than bombing. The suddenness of missile attack, combined with feelings of defenselessness, terrorized the populations of London and Teheran. Even in Tel Aviv, missile attacks had a psychological and political impact far out of proportion to the physical damage they caused (only one death was caused by some 38 missiles launched at Israel, apart from heart attacks, asphyxiations, and car accidents caused by anxiety over the attacks). Such effects can far outweigh the military significance of missile attacks. For example, by threatening to provoke Israeli retaliation, and thereby possibly break up the Arab coalition arrayed against Iraq, the “militarily insignificant” Scud played a central political role early in the 1991 Persian Gulf war.

There are also domestic and international political reasons for buying missiles instead of aircraft. Programs to develop missiles can be justified as civilian space programs, just as a nuclear weapons program can be aided and masked by a civilian nuclear program. Missiles are important symbols of prestige and technological achievement. Once a nation has acquired missiles, its rivals may be impelled to follow suit. Nations may also feel that it is easier to deter missile attack by deploying a missile force of their own rather than simply augmenting some other capability. This may explain why Saudi Arabia purchased the Chinese DF-3 missile,¹⁶ which is a exceedingly inefficient vehicle for the delivery of conventional munitions. Further, because missiles do not require pilots, better control can be maintained over their use. Missiles do not defect.

Warheads for Ballistic Missiles

Political considerations aside, nations will choose to acquire ballistic missiles rather than aircraft if the weapons they carry are so destructive that the reusability of aircraft is unimportant, or if speed of delivery is of primary importance. (This is, after all, why all five nuclear powers rely primarily on ballistic missiles.) The destructiveness and speed of delivery of nuclear-armed

¹⁶ In March 1988 Saudi Arabia announced that it had purchased DF-3 missiles (known in the west as the CSS-2) from China. Neither the price nor the number of missiles was disclosed, but 60 to 120 missiles are generally believed to have been purchased at a total cost of several billion dollars.

ballistic missiles creates the possibility of a damage-limiting preemptive attack; the lack of defenses against intercontinental ballistic missiles makes an attack virtually unstoppable. It is also much less expensive to keep a missile force on continuous alert. Thus, the desire to be able to deliver nuclear weapons quickly and surely may explain why a few states, most notably Israel and India, are developing ballistic missiles. But what about countries that have no nuclear program, or whose nuclear programs are only in their infancy? Will their ballistic missiles continue to carry conventional warheads, or will they turn to chemical or biological warheads?

CONVENTIONAL WARHEADS

Missile attacks have so far been limited to conventional warheads, but even the largest such warheads cannot do much damage. For example, the average V-2 missile landing in London killed five people, injured 13, and damaged 40 buildings with its 1-tonne warhead.¹⁷ The Scud-B, which also carries a 1-tonne warhead, would cause similar numbers of casualties in cities of comparable population density. Such missiles can only be useful in strategic attacks against cities, but a truly strategic threat (or a strategic deterrent) would require a capability to launch tens of thousands of such missiles. Conventionally armed missiles cannot be decisive militarily, and a nation certainly could not hope to deter nuclear attack by fielding a force of conventionally armed missiles.

Not surprisingly, then, as Table 2 shows, most of the nations with ballistic missile programs are also pursuing unconventional weapons. Because con-

¹⁷ The 518 V-2 missiles that landed in London killed 2754 and seriously injured 6523 people, for an average of 5.3 deaths and 12.6 injuries per missile impact. Although the energy released by the V-1 cruise-missile warhead was similar to that released by the impact of the V-2 (equivalent to 1 ton of TNT), only 2.2 deaths and 6.3 serious injuries resulted per V-1 attack, mostly because warning of the approach of the subsonic cruise missile allowed residents to take protective actions. This suggests that civil defense can reduce casualties from conventional attacks by a factor of two. U.S. Strategic Bombing Survey, Physical Damage Division, "V-Weapons in London," Report No. 152, January 1947. The effective lethal area of the V-2 warhead was about 1,500 square meters (0.15 hectares); the population density of London during the attacks was about 35 per hectare. Based on the V-2 experience, the number of deaths without warning is equal to $0.15pY^{2/3}$, where p is the population density per hectare and Y is the yield of the warhead (including its kinetic energy on impact) in tons of TNT equivalent. The modified Scuds used against Tel Aviv reportedly carried 200-kilogram warheads; since the population density of Tel Aviv is about 35 per hectare, and since warning of attack was available, one would have expected an average of about 0.7 deaths per missile impact. That the actual number of deaths in Israel was far less (one death from 11 missile impacts, six of which occurred within Tel Aviv) merely emphasizes the probabilistic nature of such attacks, as does the attack on a U.S. barracks that killed dozens of soldiers.

Table 2. Third-world ballistic missiles, nuclear weapons, chemical weapons, and biological weapons.

Country	Acquiring or trying to acquire:			
	Ballistic Missiles? ^a	Nuclear Weapons? ^b	Chemical Weapons? ^c	Biological Weapons? ^d
Afghanistan	Yes			
Algeria	Yes ^e			
Argentina	Yes	Possible	Possible	
Brazil	Yes	Possible		
Burma			Likely	
Cuba	Yes ^e		Possible	
Egypt	Yes		Likely	
Ethiopia			Likely	
India	Yes	Yes	Likely	
Indonesia	Planned		Possible	
Iran	Yes	Possible	Likely	
Iraq	Yes	Possible	Yes	Likely
Israel	Yes	Yes	Likely	
Korea, North	Yes	Possible	Likely	Likely
Korea, South	Yes		Likely	
Kuwait	Yes ^e			
Libya	Yes	Possible	Likely	
Pakistan	Yes	Likely	Likely	
Saudi Arabia	Yes		Possible	
South Africa	Yes	Likely	Possible	
Syria	Yes		Likely	Likely
Taiwan	Yes		Likely	Likely
Thailand	Possible		Possible	
Vietnam	Possible		Likely	
Yemen	Yes			

SOURCES:

- a. Aaron Karp, "Ballistic Missile Proliferation," in Stockholm International Peace Research Institute [SIPRI], *SIPRI Yearbook 1990* (Oxford: Oxford University Press, 1990); and Statement of Rear Admiral Thomas A. Brooks, Director of Naval Intelligence, before the Seapower, Strategic, and Critical Materials Subcommittee of the House Armed Services Committee, March 7, 1991.
- b. Leonard S. Spector, *Nuclear Ambitions: The Spread of Nuclear Weapons, 1989-90* (Boulder, Colo.: Westview Press, 1990).
- c. Elisa D. Harris, "Chemical Weapons Proliferation: Current Capabilities and Prospects for Control," in Aspen Strategy Group, *New Threats: Responding to the Proliferation of Nuclear, Chemical, and Delivery Capabilities in the Third World* (Washington, D.C.: University Press of America, 1990); and Statement of Rear Admiral Thomas A. Brooks.
- d. Statement of Rear Admiral Brooks; and Statement of Admiral William O. Studeman before the Seapower, Strategic, and Critical Materials Subcommittee of the House Armed Services Committee, March 1, 1988.
- e. Short-range (less than 100 kilometers) missiles only.

ventional weapons lack destructive power and nuclear weapons are difficult to develop, many believe that chemical or biological weapons will soon be the warhead of choice for emerging ballistic missile arsenals.

CHEMICAL WARHEADS

Chemical weapons have been used in war since ancient times, but they have never been delivered by modern ballistic missiles. Over 100,000 tons of chemical agents were released by artillery shells, mortars, bombs, grenades, and gas cylinders in World War I, producing about 100,000 fatalities and over 1,000,000 total casualties.¹⁸ More potent chemical weapons were developed and stockpiled by Germany, the United States, the United Kingdom and other combatants in World War II, but their uncertain military utility, combined with the deterrent effect of opposing chemical arsenals, prevented their use. Nazi Germany examined the possibility of arming the V-2 missile with chemical agents, but decided to use high explosives because their effects were more predictable and reliable, and because they feared allied chemical retaliation against German cities.

It is not clear how nations will choose in the future. The most deadly use of chemical weapons since World War I occurred during the Iran-Iraq war.¹⁹ Even though both nations were armed with ballistic missiles, they used aircraft and artillery, not ballistic missiles, to deliver chemical agents.²⁰

¹⁸ For a review of the development, use, and alleged use of chemical weapons, see SIPRI, *The Problem of Chemical and Biological Warfare*, Vol. I: *The Rise of CB Weapons*, (New York: Humanities Press, 1971); and Victor A. Utgoff, *The Challenge of Chemical Weapons: An American Perspective* (London: Macmillan, 1990).

¹⁹ Other large-scale uses of chemical agents since World War I include the use of lethal agents by Italy in its 1935–36 invasion of Ethiopia, by Japan during its occupation of Manchuria from 1937–45, and by Egypt during their intervention in the civil war in Yemen during the mid-1960s. Several unsubstantiated claims of large-scale uses of lethal agents have also been recorded, including alleged uses of chemicals by the United States against North Korea, by Vietnam against Laos and Kampuchea, and by the Soviet Union in Afghanistan. In terms of tonnage, the largest use of chemical agents since World War I was the use of herbicides and non-lethal agents by the United States in Vietnam, but the United States maintains that such agents are not covered by the Geneva protocol.

²⁰ Most analysts believe that neither country had the technical capability to mount chemical weapons on ballistic missiles during the war, and there is much debate about whether Iraq had acquired this capability before the 1991 Persian Gulf war. It is unclear, however, why nations that could manufacture chemical artillery shells would find it especially difficult to arm missiles with chemical warheads. See Thomas L. McNaugher, *International Security*, Vol. 15, No. 2, (Fall 1990), pp. 5–34, for a description and evaluation of the use of chemical agents and ballistic missiles in the Iran-Iraq war.

It is often claimed that one to two dozen countries stockpile or are actively seeking chemical weapons (see Table 2), but only the United States, the Soviet Union, and Iraq openly admit to stockpiling (and Iraq, to using) such weapons. Of those nations with ballistic missiles, Egypt, India, Iran, Israel, North and South Korea, Libya, Pakistan, Syria, and Taiwan are strongly suspected of stockpiling or producing chemical weapons.²¹ While the United States and the Soviet Union are the only countries known to have outfitted missiles with chemical warheads, there are strong suspicions that Syria and Iraq have attempted to do so.²²

CHEMICAL AGENTS. A variety of chemical agents have been developed that can kill and incapacitate. Choking agents, of which phosgene is the most lethal example, attack the respiratory system, causing irritation and inflammation of the bronchial tubes and lungs.²³ At lethal concentrations the lungs become so full of fluid that the victim dies of anoxia. Blood agents, such as hydrogen cyanide, act by preventing the utilization of oxygen in the blood.²⁴ Choking and blood gases are respiratory agents, and are therefore readily defeated by gas masks. Blister agents, of which mustard is the best known, can injure and kill by absorption through the skin as well by inhalation of vapors or aerosols.²⁵ Because they are liquids at normal temperatures, their dissemination is easier to control than a gas. These properties made blister agents the most effective chemical agents at the end of World War I.

Nerve agents, first discovered in Germany shortly before World War II, are far more deadly than the choking, blood, and blister agents used in World War I. Nerve agents work by interfering with cholinesterase, an enzyme involved in nerve transmission. Symptoms of nerve-agent poisoning include sweating, nausea, vomiting, staggering, coma, and convulsion, followed by cessation of breathing and death. When inhaled, nerve agents are lethal in concentrations over ten times smaller than choking, blood, or blister agents; like mustard, nerve agents are readily absorbed through the skin.

²¹ Statement of Rear Admiral Thomas A. Brooks, Director of Naval Intelligence, before the Seapower, Strategic, and Critical Materials Subcommittee of the House Armed Services Committee, March 7, 1991.

²² Iraq recently revealed that it possesses 30 chemical warheads for its modified Scud missiles, but details about the design of the warheads is not publicly available. Iraq also disclosed supplies of 75 tons of Sarin and 500 tons of Tabun. See Don Oberdorfer and Ann Devroy, "State Department Calls Iraq's Figures on Weapons 'Short of Reality'," *Washington Post*, April 20, 1991, p. A15.

²³ Other common choking agents include chlorine, chloropicrin, and diphosgene.

²⁴ Other common blood agents include cyanogen chloride and arsine.

²⁵ Other common blister agents include lewisite and various nitrogen mustard compounds.

They vary in consistency from sarin, which is watery and volatile, to VX, which has the viscosity of motor oil. Production costs are low—as little as \$10–20 per kilogram of agent.²⁶

The lethality of chemical agents is typically stated in terms of the LCt₅₀, which is the product of the concentration of the agent in air in milligrams per cubic meter (mg/m³), multiplied by the length of the exposure in minutes that would result in death to 50 percent of the adults exposed.²⁷ The ICt₅₀ is the dose that would result in militarily significant incapacitation to half of the exposed population. The LCt₅₀ and ICt₅₀ for various chemical agents are given in Table 3.

CHEMICAL WARHEAD DESIGN. The United States and the Soviet Union are the only two countries known to have developed chemical warheads for ballistic missiles. The chemical warheads developed by the United States for the Little John, Honest John, and Sergeant missiles carry a large number of bomblets, each filled with a small amount of agent (about 600 grams of sarin or VX). The height at which the bomblets are released determines the diameter of the impact pattern on the ground. A burster charge containing a few hundred grams of high explosive detonates when the bomblets strike the ground, creating a small cloud of agent. Agent comprises 30–40 percent of the total weight of these warheads.²⁸

Soviet chemical warheads are designed quite differently. Diagrams of the FROG and Scud-B warheads displayed at the Soviet Shikhany Central Proving Ground in October 1987 show a small, cylindrical burster charge surrounded by a large amount of liquid agent. According to the diagram, the 985-kilogram Scud warhead contains 555 kilograms of thickened VX; the burster charge appears to contain about 20 kilograms of high explosive.²⁹

²⁶ The United States produced sarin for about \$3/kilogram during 1954–56 and VX for about \$5/kilogram during 1961–67, which is equivalent to \$12/kilogram and \$18/kilogram at today's prices. SIPRI, *The Problem of Chemical and Biological Warfare*, Vol. II: *CB Weapons Today* (New York: Humanities Press, 1973), p. 53. Producing the agent would therefore cost a few thousand dollars per missile, assuming that a 1-tonne missile warhead would contain 300 kilograms of agent.

²⁷ For example, the LCt₅₀ of sarin is 100 mg-min/m³, meaning that exposure to a concentration of 10 mg/m³ for 10 minutes or 100 mg/m³ for 1 minute would be fatal to half those exposed.

²⁸ The 110-kilogram M206 warhead for the Little John contained 31 kilograms of GB; the 560-kilogram M79 and M190 warheads for the Honest John contained 177 and 217 kilograms of GB; the 680-kilogram M213 warhead for the Sergeant contained 195 kilograms of GB. Agent masses from SIPRI, *CB Weapons Today*, p. 84; warhead masses from Cochran, et al., *U.S. Nuclear Forces and Capabilities*.

²⁹ S.J. Lundin, J.P. Perry-Robinson, and Ralph Trapp, “Chemical and Biological Warfare: SIPRI Yearbook 1988: *World Armaments and Disarmament*

Table 3. The properties of various chemical agents.

Agent	Volatility (mg/m ³) ^a	Respiratory ^b		Percutaneous ^c
		Lethal Dose LC ₅₀ (mg- min/m ³)	Incap. Dose IC ₅₀ (mg-min/m ³)	Lethal Dose LC ₅₀ (mg-min/m ³)
Tabun (GA)	610	400	300	40,000
Sarin (GB)	22,000	100	75	15,000
Soman (GD)	3,900	100	75	10,000 ^d
VX	10	100	50	1,000 ^d
Mustard (HD)	920	1500	200	10,000
Phosgene (CG)	4,000,000	3200	1600	n.a.
Hydrogen Cyanide	1,100,000	5000 ^e	2000 ^e	n.a.

SOURCE:: FM 3-9, *Military Chemistry and Chemical Compounds* (Washington, D.C.: Department of the Army, October 1975).

NOTES: These estimates are for resting, unprotected adults; for highly active adults (e.g., soldiers in heavy combat or civilians running for cover after a missile attack) or for children, the LC₅₀ and IC₅₀ could be three to four times lower.

a. Mass of vapor per cubic meter of air at 25° C. For comparison, the volatility of water at 25° C. is 23.8 mg/m³.

b. Median lethal and incapacitating dosage for unprotected men breathing at a rate of 10 liters per minute.

c. Median lethal dosage for men in ordinary combat clothing.

d. Stockholm International Peace Research Institute, *The Problem of Chemical and Biological Warfare*, Vol. II: *CB Weapons Today* (New York: Humanities Press, 1973), pp. 42-43.

e. Depends on concentration; values given here are for a concentration of 100 mg/m³. LC₅₀ = 2000 mg-min/m³ at a concentration of 200 mg/m³.

Apparently the warhead shell is fragmented by the burster charge hundreds of meters above the ground, and wind-shear forces break the exposed liquid into droplets, which rain onto the ground below.

The effects of chemical agents depend largely on the size of the aerosol particles. Particles with diameter greater than 10 microns pose a hazard via direct absorption through the skin or, in warm weather, by the evaporation and subsequent inhalation of the vapors. Aerosols larger than 10 microns pose relatively little inhalation hazard since such particles are trapped by the upper respiratory tract, where absorption into the bloodstream is slow. Al-

(Oxford: Oxford University Press, 1988), p. 111; *Soviet Military Power: An Assessment of the Threat 1988* (Washington, D.C.: U.S. Department of Defense, 1988), p. 77.

though spray tanks can efficiently distribute agent as a fine aerosol, missile warheads using explosive charges probably cannot disperse more than one-half of the agent as particles with diameters of less than 5 microns, the particle sizes that maximize retention in the lung and absorption into the bloodstream.

Large particles settle quickly onto the target below, heavily contaminating a relatively small area; aerosols, on the other hand, drift with the wind, posing an inhalation hazard over a much larger area. Since large particles are not readily inhaled and do not stay airborne for long, the primary hazard is skin contact with the agent. For this reason, persistent agents are usually made into coarse aerosols, so that a particular target (e.g., an airstrip) can be made unusable, except by protected personnel, for an extended period of time. For strategic attacks against unprotected civilians, an agent capable of forming a fine (less than 5-micron-diameter) aerosol would have the greatest potential for causing deaths over a large area. The U.S. Army recommends using the more volatile agent sarin (rather than VX) against troops that are unprotected or who are carrying, but not wearing, masks.³⁰ Fine aerosols are carried along by the wind, gradually diluted by atmospheric turbulence and removed by deposition onto the ground, forming cigar-shaped dose contours.

The concentration of agent downwind from a chemical attack depends on the mass of agent released, the size of the particles, the height of burst, and the initial size of the aerosol cloud, as well as the atmospheric stability, wind speed, mixing height, and temperature. Since the United States has undoubtedly conducted extensive tests, it is reasonable to assume that current U.S. warheads can disseminate sarin as a fine aerosol with reasonable efficiency. While it should not be too difficult for Third World countries to develop the chemical-bomblet warhead technology that the United States had in the 1950s, it would be far easier and more efficient to spray chemical agents from aircraft or cruise missiles. Indeed, Iraq primarily used helicopters, which it bought from the United States for crop dusting, to spray lethal chemical agents on Kurdish civilians in 1988.³¹

To explore the range of casualties that might result from chemical attacks on unprotected civilians, a dispersion model was developed to predict the

³⁰ FM 3-10, *Employment of Chemical Agents* (Washington, D.C.: Department of the Army, March 1966), p. 19.

³¹ Stuart Auerbach, "\$1.5 Billion in U.S. Sales to Iraq," *The Washington Post*, March 11, 1991, p. A1, A16.

areas that would receive lethal or incapacitating doses under a variety of conditions and assumptions.³² Calculations were done for ground-level releases of 100 to 1000 kilograms of agent on urban targets under three sets of weather conditions: a clear, sunny day with a light breeze; an overcast and windy day or night; and a clear, calm night.³³ The agent was assumed to be released by the missile warhead in three different forms: as vapor over a period of hours, instantaneously as a fine aerosol, or half as vapor and half as fine aerosol, with an initial cloud diameter of 50 to 150 meters. The results, given as the area covered by doses greater than the lethal or incapacitating dose to mildly active, unprotected adults per tonne of agent released, are given in Table 4. In general, elevated releases, coarser aerosols, and larger initial cloud sizes lead to smaller lethal areas than small, ground-level clouds of fine aerosol.

Assuming that about half of the agent is disseminated as a fine aerosol (with most of the remainder evaporating within a few hours in warm weather), the lethal area ranges from about 20 to 40 hectares per tonne³⁴ (ha/te) of agent released, under the least favorable weather conditions explored, to 250 to 400 ha/te under the most favorable conditions for an attacker. The corresponding areas for incapacitating effects are an additional 20 to 50 ha/te for unfavorable conditions and 300 to 400 ha/te for favorable conditions.

It should be noted that the least favorable conditions explored here are relatively unfavorable (from the attacker's point of view) but reasonably likely conditions; much higher wind speeds or larger aerosol particles would decrease these areas substantially. On the other hand, the most favorable

³² The model was verified by comparing its results with U.S. Army estimates of the number of sarin-filled 105-millimeter, 155-millimeter, and 8-inch artillery shells required to produce 50 percent casualties among mildly active, unprotected troops over an area of one hectare. Good agreement was obtained over a variety of stability conditions and wind speeds by assuming that 50 percent of the agent is released in a small cloud of fine aerosol at ground level over rural terrain, and that at high temperatures the remaining 50 percent evaporates in a matter of hours. See FM 3-10, *Employment of Chemical Agents*, pp. 97-99. Under a reasonable set of assumptions, the model also showed good agreement with estimates presented by the IISS, *The Military Balance 1988-89*, p. 248, for the effects of chemical attacks with Soviet Scud and FROG missiles. A detailed description of the model (and the computer model itself) will be made available upon request to the author.

³³ Stability is a measure of the tendency of air near the ground to mix vertically. During unstable conditions mixing is rapid; during stable conditions air is trapped near the ground. In general, unstable conditions occur during clear, calm days; stable conditions occur during clear, calm nights. Extensive cloud cover or high wind speeds create neutral conditions (i.e., air near the ground tends neither to rise or sink).

³⁴ One hectare (ha) = 10,000 square meters = 0.01 square kilometers = 2.5 acres. An average city block covers an area of about two hectares.

Table 4. The areas over which unprotected adults would receive lethal and incapacitating doses of sarin, per tonne of agent released.

Weather Conditions ^a	Agent Form ^b	Area Affected (hectares/tonne)	
		Lethal Dose	Incapacitating Dose
Clear, sunny day, light breeze	vapor	10 – 18	26 - 37
	a/v	17 - 32	47 - 64
	aerosol	29 - 48	73 - 94
Overcast with moderate wind, day or night	vapor	9 - 16	13 - 34
	a/v	19 - 37	27 - 83
	aerosol	37 - 63	54 - 150
Clear, calm night	vapor	150 – 460	420 - 1300
	a/v	260 – 400	590 - 820
	aerosol	240 – 430	380 - 900

NOTES: Assumes LC₅₀ of 70 mg-min/m³ and IC₅₀ of 35 mg-min/m³ (appropriate for mildly active, unprotected men), for releases of 100 to 1,000 kilograms of sarin on an urban target.

- b. “Clear, sunny day, light breeze” corresponds to Pasquill class “A” stability for residential urban areas, a mixing height of 2,000 meters, and a wind speed of 2 meters per second; “overcast” corresponds to class “D” stability, a mixing height of 1,000 meters, and a wind speed of 5 meters per second; “clear, calm night” corresponds to class “F” stability, a mixing height of 250 meters, and a wind speed of 1 meter per second.
- c. a/v = 50 percent fine aerosol, 50 percent vapor. The deposition velocity is assumed to be 0.01 meters per second for a fine aerosol, 0 meters per second for vapor.

weather conditions explored here are not uncommon—at one desert location in the southwestern United States such conditions occur about one-third of the time.³⁵ Because the attacker chooses the time and place of an attack, it can therefore control to some extent the weather conditions during an attack.³⁶

If we assume that the average chemical warhead is 30 percent agent by weight, and that about half of the agent is released as respirable aerosol, then under even relatively unfavorable conditions a sarin-armed missile with

³⁵ *Reactor Safety Study* (Washington, D.C.: U.S. Nuclear Regulatory Agency, WASH-1400, 1975), Appendix VI, p. 5-3.

³⁶ Although Third World countries may not have weather satellites, commercial weather forecasts, news broadcasts, or even spies could be used to determine weather conditions in remote cities, even during war.

a throwweight of 1 tonne could kill unprotected people over an area of 6 to 10 hectares and incapacitate over another 8 to 11 hectares. Under favorable conditions for an attacker, unprotected people would be killed over an area of 100 hectares and incapacitated over an additional 120 hectares. If used against an unprepared city with a population density of 35 per hectare (e.g., Tel Aviv or Riyadh), 200 to 3,000 people would be killed and a somewhat greater number seriously injured, depending on the weather conditions. This is 40 to 700 times as many deaths, and 20 to 300 times as many injuries as would result from the same missile armed with a conventional warhead.³⁷ Since many cities in the Middle East and Asia have much greater population densities (e.g., 100 to 300 per hectare),³⁸ the potential exists for huge numbers of deaths in unprotected civilian populations.

DEFENSE AGAINST CHEMICAL AGENTS. While it is possible to protect civilians against chemical attack, protection is never perfect. It is commonly assumed that by remaining indoors and closing all doors and windows the dose can be greatly reduced, but in fact agent will still leak in. Even tightly sealed dwellings will not afford much protection unless they are thoroughly ventilated as soon as the cloud passes, for otherwise the occupants will receive about the same dose as unprotected individuals, but at a slower rate.³⁹ Gas masks provide protection against all but very high concentrations of nerve agent, but they must be applied immediately and they must fit properly. Even among soldiers carrying masks and trained for chemical combat, the U.S. Army estimates that 4 to 8 percent of troops that would have died

³⁷ See footnote 17.

³⁸ Average population densities of major cities range from 25 (Miami) to 1,000 (Hong Kong) per hectare. Most cities have 30 to 300 people per hectare, with western cities at the lower end and older Asian cities at the upper end of this range. The average population densities of selected Asian and Middle Eastern cities are as follows: Bombay, 41; Haifa, 100; Baghdad, Istanbul, and Karachi, 130; Ankara and Kiev, 160; Calcutta, 190; Delhi, 200; Teheran and Lahore, 240; Alexandria, 290; Cairo, 320. *The World Almanac* (New York: Pharos, 1989), pp. 738-739.

³⁹ If people remain inside buildings for several hours, the dose inside will be nearly equal to the dose outside. To see this, consider a house of volume V in which the residence time of air is τ ; air will flow into the house at a rate of V/τ . If the concentration of agent in the outside air is C for the time of the cloud passage t , then amount of agent flowing into the house is $C(V/\tau)t$, and the concentration of agent inside the house, c , is equal to Ct/τ . Therefore, the time-integrated dose inside the house ($c\tau$) is equal to the dose outside (Ct). If the building is tightly sealed, τ will be large (e.g., 10 hours) and c will be much smaller than C , and occupants can greatly decrease their total dosage by ventilating the house after the cloud passes. To do this, however, the occupants must be told when it is safe to go outside. A series of chemical attacks, or fears of additional attacks, could keep people in their houses for many hours (comparable to the residence times of air in western dwellings). In fact, residents of Tel Aviv were kept in their houses for hours at time merely in anticipation of such attacks.

without masks will die nevertheless because of delayed masking, mask leakage, defective or missing masks, or early unmasking.⁴⁰ The percentage of masking errors among civilians would undoubtedly be much higher; it seems unlikely that even the best civil defense program could reduce fatalities to much less than 10 percent of the number that would die without protection.

Depending on the circumstances, chemical weapons can be a minor nuisance or weapons of mass destruction. Based on the example given above, chemical warheads are likely to be more deadly than conventional munitions even if used against a well-prepared population under unfavorable weather conditions,⁴¹ they may be 50 times more deadly if civil defense is ineffective *or* weather conditions are favorable, and 500 times more deadly than conventional warheads when used against unprepared populations under favorable weather conditions. (Compared to a Hiroshima-sized nuclear weapon, chemical warheads would result in 1/10 to 1/2000 of the number of deaths.)⁴² In view of these estimates, it is not hard to see why a Third World military planner with a limited number of inaccurate but expensive missiles might prefer chemical over conventional warheads.

Although they are capable of causing widespread death and suffering, chemical warheads do not constitute a “poor man’s atom bomb,” especially if used against a well-prepared adversary. Biological weapons, in contrast, could approach nuclear weapons in lethality.

BIOLOGICAL WARHEADS

No nation is known to possess biological weapons today, but the United States, the United Kingdom, and Japan are known to have developed several types of biological weapons in the past (such stocks have since been destroyed), and Iraq and Syria are strongly suspected of stockpiling such weapons today.⁴³

⁴⁰ FM 3-10, *Employment of Chemical Agents*, p. 36.

⁴¹ If chemically armed missiles are to be no more deadly than similar missiles armed with high explosives, civil defenses would have to limit deaths to no more than 1 percent of the number that would die without protection. Such a high degree of protection seems extremely unlikely.

⁴² Based on the bombings of Hiroshima and Nagasaki, the lethal area of a 20-kiloton nuclear weapon is about 10 square kilometers (1,000 hectares). Samuel Glasstone and Philip J. Dolan, *The Effects of Nuclear Weapons* (Washington, D.C.: U.S. Department of Defense, 1977), p. 544.

⁴³ The United States believes that Iraq has anthrax as well as botulism warheads. Statement of Rear Admiral Thomas A. Brooks, March 7, 1991.

Biological agents can be divided into two distinct categories: toxins (toxic chemicals produced by living organisms)⁴⁴ and pathogens (living organisms that produce disease). One of the most studied toxins is botulinal toxin, which is lethal at concentrations a thousand times smaller than sarin. Botulinal toxin is not suited to air delivery (especially by ballistic missile) because it decays rapidly upon exposure to air. In fact, experiments in which clouds of botulinal toxin were released over lines of tethered animals showed that the number of deaths caused would not be much greater than that from an equal quantity of nerve agent.⁴⁵ Other toxins have been studied, but none seems to have convincing advantages over nerve agents for strategic missile attacks.

Pathogens, on the other hand, may have significant advantages over nerve agents in their ability to kill large numbers of civilians. In particular, *bacillus anthracis*, the bacteria that causes anthrax, seems especially well suited for dissemination by missiles or bombs because of its ability to form spores that can survive violent dissemination methods and exposure to sun, air, and rain. Because anthrax is not an infectious disease, it can be used as discriminately as chemical agents. Anthrax bacteria are deadly in concentrations a thousand times smaller than nerve agents, with an estimated EC_{t50} (the dose at which 50 percent of the exposed population would contract the disease) of only 0.1 mg-min/m³. Left untreated, anthrax kills nearly all who contract it within a few days. Although vaccines are available, they must be administered before exposure and their effectiveness against massive doses is uncertain. Mass vaccination programs are unlikely to be popular unless the situation is obviously dire. Treatments with antibiotics have been developed, but patients must be treated early, before symptoms of the disease are apparent. It is doubtful whether sufficient stocks of antibiotics would exist to treat the hundreds of thousands of people that might believe that they were infected during an attack on a large city, let alone enough medical personnel to administer the injections in the short time available (a day or two).

Table 5 gives the EC_{t50}, incubation period, and mortality rate for *bacillus anthracis* and several other pathogens. Some pathogens have an EC_{t50} that is much lower than that of anthrax, but the mortality rates are usually lower, the incubation times are longer, the pathogens are more difficult to dissem-

⁴⁴ Toxins have been produced synthetically, which blurs the distinction between toxin and chemical agents. The classification of toxins as biological rather than chemical agents dates back to a time when this was not possible.

⁴⁵ SIPRI, *CB Weapons Today*, p. 60.

Table 5. Pathogens considered for use as biological weapons.

Pathogen	Disease	Respiratory ECt ₅₀ ^a (mg-min/m ³)	Time to Effect (days)	Mortality Rate (percent)
<i>F. tularensis</i>	Tularemia	0.001	2–5	0–60
<i>B. anthracis</i>	Anthrax	0.1	1–4	95–100
<i>P. pestis</i>	Plague	b	3–4	90–100
<i>C. burnetii</i>	Q fever	0.001	18–21	1–4
VEE virus	VEE	0.001	2–5	0–2

SOURCE: Stockholm International Peace Research Institute, *The Problem of Chemical and Biological Warfare*, Vol. II: *CB Weapons Today* (New York: Humanities Press, 1973), pp. 42–43.

NOTES:

- a. Median pathogen dosage that would produce the disease in resting, unprotected men, assuming agent-infested particles with diameters of 1 to 5 microns, and assuming that a fraction of the organisms die during dissemination (95 percent for tularemia, 50 percent for anthrax, 90 percent for Q fever, and 80 percent for VEE).
- b. Plague is highly contagious; the number of people exposed to a given concentration of the *pasteurella pestis* bacteria would not be an accurate indication of how many people would eventually contract the disease. A dose of about 3,000 bacteria per man would result in a 50 percent probability of contracting the disease.

inate and less hardy when airborne, or the diseases are contagious, making these agents less useful than *bacillus anthracis* for strategic missile attacks. The possibility that suitable pathogens remain to be discovered that are a hundred times more lethal than *bacillus anthracis* cannot be ruled out, however.

As above, a dispersion model was used to estimate the areas that would receive a given concentration of pathogen for attacks with 10 to 100 kilograms of agent distributed as a fine aerosol.⁴⁶ Doses greater than 0.1 mg-min/m³ (the estimated ECt₅₀ for anthrax) can be produced over 20 to 40 hectares per kilogram of bacteria released on a calm, sunny day; 65 to 100 ha/kg for a

⁴⁶ The range of delivered biological agent masses are assumed to be ten times smaller than the range of delivered chemical agent masses because biological agents are more difficult and fragile to disperse and more expensive to produce, and because more casualties could be reliably produced by distributing the available agent among many missiles. See, for example, Matthew Meselson, Martin M. Kaplan, and Mark A. Mokulsky, "Verification of Biological and Toxin Weapons Disarmament," in Francesco Calogero, Marvin L. Goldberger, and Sergei P. Kapitza, eds., *Verification: Monitoring Disarmament* (Boulder, Colo.: Westview, 1991), p. 152.

windy, overcast day; and 30 to 260 ha/kg for a calm, clear night. Kilogram for kilogram, anthrax produces lethal concentrations over an area about one thousand times larger than does sarin; warhead for warhead, roughly one hundred times larger.

To illustrate the magnitude of the casualties that could be produced by biological weapons, consider a missile armed with 30 kilograms of anthrax spores. Lethal doses to unprotected adults would result over an area of 6 to 80 square kilometers, depending on the weather conditions and assumptions about the release; since the cigar-shaped lethal area would extend 10 to 30 kilometers downwind, only 5 to 25 square kilometers of the lethal area might lie within the targeted city.⁴⁷ Even with civil defense, the effective lethal area might be 0.5 to 2 square kilometers. (For comparison, the lethal area of a Hiroshima-type fission bomb is about 10 square kilometers.) Thus, even when used against a prepared population, anthrax warheads could rival small nuclear weapons in their ability to kill people, although the outcome would be highly unpredictable due to uncertainties in the weather and the effectiveness of dissemination, civil defense, and medical treatment.

Unlike chemical agents, the most persistent of which might pose a continuing hazard to large numbers of humans for up to a few weeks, anthrax spores could survive for decades in soil; unless extensive decontamination measures are taken, spores in resuspended dust could continue to infect people years after an attack. During World War II, Britain, Canada, and the United States detonated experimental anthrax bombs on Gruinard Island; the island was only declared safe again in 1988 after burning the heather and treating the ground with formaldehyde.⁴⁸ It is difficult to make quantitative estimates of the number of people that might be exposed in this way because of uncertainties in evacuation and decontamination procedures, the lifetime of the spores, the concentration of resuspension spores as a function of time, and the time dependence of the dose-response relationship.⁴⁹ The persistency of agents such as anthrax would limit the usefulness of such weapons in

⁴⁷ A city of one million inhabitants with an average population density of 35 per hectare would have a diameter of roughly 10 kilometers. If warheads are detonated in the optimal location (on the edge of the city on its windward side), then at most only the first 20 kilometers of the lethal area would lie within the city.

⁴⁸ L.M. Astra, "Germ and Ideas: What the Public Record Says About Chemical and Biological *City Paper*, February 22, 1991, p. 11.

⁴⁹ For example, inhaling a thousand spores a day for a thousand days will not result in the same effects as inhaling a million spores in a single day.

taking and holding territory, but it would not necessarily make the threat to use such weapons less credible than the threat to use nuclear weapons.

Table 6 gives rough estimates of the number of people that might be killed in a large, sparsely populated city by a missile armed with a conventional, chemical, biological, or nuclear warhead, with and without effective civil defenses. Up to ten times as many casualties would result if these weapons were used in a densely populated city such as Cairo, Teheran, or Lahore. In very rough terms, a relatively small (20-kiloton) nuclear warhead is 10,000 times as destructive as a 1-ton conventional explosive, 10 to 100 times as deadly as a nerve-agent warhead, but no more deadly than an anthrax warhead used against an unprotected population. Used against a well-protected population, nuclear weapons are 100 to 1,000 times more deadly than chemical weapons and about 10 times as deadly as an anthrax warhead.

Do chemical and biological weapons qualify as “weapons of mass destruction,” and should we think about these weapons in the same way that we have come to think about nuclear weapons? Anthrax weapons (or weapons using similarly lethal pathogens) certainly are able to kill enough people to qualify for this dubious distinction, even if they cannot knock over buildings.

Table 6. A comparison of the casualties produced by nuclear, chemical, biological, and high-explosive warheads.

Type of Warhead	Without Civil Defense		With Civil Defense	
	Dead	Injured	Dead	Injured
Conventional (1 tonne of high explosive)	5	13	2	6
Chemical (300 kilograms of sarin)	200–3,000	200–3,000	20–300	20–300
Biological (30 kilograms of anthrax spores)	20,000–80,000		2,000–8,000	
Nuclear (20 kilotons)	40,000	40,000	20,000	20,000

NOTES: Assumes a missile with a throwweight of 1 tonne aimed at a large city with an average population density of 30 per hectare. Assumes that civil defenses reduce casualties from conventional and nuclear explosions by a factor of two, and casualties from chemical and biological weapons by a factor of ten.

Whether or not chemical warheads should be classified as massively destructive appears to depend on the willingness and the capacity of civilian populations to prepare for such attacks. While civil defense is relatively straightforward, one should bear in mind that the capacity of many Third World nations to prepare and train for chemical attacks is limited; many western nations, while possessing the capacity, lack the willingness to prepare.⁵⁰ In the final analysis, however, it depends on the threshold of pain in a particular country or region. Western nations often react violently to events that involve even a handful of civilian deaths. Thus, while chemical weapons may be hundreds or thousands of times less deadly than nuclear weapons, chemical attacks on western nations may well trigger political and military responses similar to those that would be provoked by nuclear or anthrax attacks.

Why Should We Care About Proliferation?

There are five reasons that we should be at least as concerned about the proliferation of weapons of mass destruction in the future as we have been about nuclear proliferation in the past: (1) proliferation complicates U.S. foreign policy; (2) crisis instabilities are likely to be more severe; (3) the probability of inadvertent or accidental use is likely to be greater; (4) transfers to terrorist or subnational groups are more likely; and (5) at least some of the future possessor nations are likely to be politically unstable, aggressive, and difficult to deter.

To see how missile proliferation, coupled with unconventional warheads, might complicate foreign policy, consider how the response to the Iraqi invasion of Kuwait might have been different if Iraq had possessed the capability to launch chemical, biological, or nuclear weapons against Paris or London. In the face of such a threat, would France and the United Kingdom have joined the United States in attacking Iraq? Indeed, if Iraq threatened to hold European cities “hostage,” would even the United States have risked an attack? And if Iraq carried out threats to launch such weapons at the first notice of an allied attack, how would the United States and its allies have

⁵⁰ The dismal history of civil defense precautions against nuclear attack in the United States should give pause to anyone contemplating a similar program to guard against chemical or biological attack. See, for example, Robert Scheer, *With Enough Shovels: Reagan, Bush, and Nuclear War* (New York: Vintage, 1983).

responded? The result would not necessarily be total paralysis; in the case of Iraq, for example, the United States could have preemptively destroyed missile sites, as it did in the war. If weapons were launched nevertheless, massive conventional attacks would have been adequate to punish and defeat Iraq.

With regard to crisis instability, Third World weapons are more vulnerable to preemptive attack than are the forces of the nuclear powers, whether based on missiles or aircraft. The short distances separating nations in the Middle East make airbases and missile launch sites tempting targets for preemptive strikes; ballistic missiles, either with more accurate or with more powerful warheads, make it possible to attack such targets in just a few minutes. While light-weight missiles such as the Scud are readily mobile and thus can be difficult to destroy if dispersed throughout the countryside, longer-range missiles weighing more than ten or twenty tonnes are too heavy to be truly mobile and probably would be launched from a few (perhaps hardened) fixed sites. Missiles have the advantage of not requiring visible facilities such as airstrips, but, unlike aircraft, missiles cannot escape attack without being used offensively.

Although missiles themselves may not significantly worsen the vulnerability problem, weapons of mass destruction might, because the benefits that could be derived from a successful first strike would be much greater. Just as the early U.S. and Soviet nuclear forces were vulnerable to preemptive attack, so may emerging arsenals of mass destruction in the Third World create instability. If, during a crisis, one side believes that war is inevitable, it may try to preemptively destroy the other side's vulnerable but valuable weapons of mass destruction. Even if both sides prefer not to preempt, each may fear that the other side will; consequently, both may decide to launch at the first (perhaps false) indication of an attack. This crisis-stability problem is even worse than the one faced by the superpowers,⁵¹ because warning of an attack will be shorter, because of the shorter range, and much less reliable, because of the primitive intelligence-gathering capabilities of most Third World nations. The United States and the Soviet Union have managed to keep their nuclear forces on constant alert for three decades without an accidental launch. It is open to question whether the new missile states,

⁵¹ For a discussion of crisis stability in the superpower context, see Desmond Ball, et al., *Crisis Stability and Nuclear War* (Ithaca, N.Y.: Cornell University, 1987).

lacking the wealth, technology, and political stability of the superpowers, can be expected to compile as good a record.

The possibility of unauthorized use or accident also creates dangers. Although political control over weapon systems may be very strong in authoritarian states, unauthorized use and accidental launches are not physically prevented by sophisticated permissive action links and environmental sensing devices such as those used in U.S. nuclear weapons. A group of military officers could use or threaten to use such weapons on their own authority, either to satisfy an overzealous hatred of the enemy or to blackmail their own civilian government.

The probability of large-scale attacks by subnational or terrorist organizations will be far more worrisome as weapons of mass destruction spread to Third World countries that sponsor acts of terrorism, such as Iran, Iraq, Libya, North Korea, and Syria. If the supplier of such weapons is known, victim nations could respond by retaliating against the supplier nation; but if the supplier cannot be positively identified, a forceful response to an anonymous attack could trigger widespread resentment, especially if the suspected supplier can plausibly deny its involvement. Terrorist attacks might also be calculated to catalyze war between two states.

With the possible exception of the Soviet Union in recent times, the nuclear powers exhibit an exceptional degree of internal political stability. Many of the potential proliferators listed in Table 2 do not enjoy the same degree of stability. Some states, such as Afghanistan, Iraq, and South Africa, have deep internal divisions. Other pairs of states, such as India and Pakistan, North and South Korea, Israel and various Arab states, have deep religious, ideological, or cultural animosities, often combined with active border disputes, that weaken deterrence. Some authoritarian states are ruled by aggressive dictators such as Libya's Muammar Qaddafi or Iraq's Saddam Hussein, who have little regard for international norms of behavior. Many of the new missile states are simply unhappy with the status quo, and may look to their newly acquired capabilities for mass destruction as instruments of intimidation and change. The probability of conflict within and among the new missile states will be substantially higher than has been the case with the present nuclear powers, which increases the probability that weapons of mass destruction will be used. Even if the United States or its allies were not directly threatened, we should still be concerned because of the human suffering that would result from the use of such weapons.

What Can We Do About Proliferation?

The United States has a declarative policy of preventing the proliferation of weapons of mass destruction, but this policy has been applied rather unevenly over time and among nations. Many of these inconsistencies have resulted from balancing the goal of nonproliferation against other goals of U.S. policy, such as containing the Soviet Union, supporting the state of Israel, or balancing the trade deficit. In most cases nonproliferation has taken a back seat to these other goals. It is time to give nonproliferation higher priority.

Possible policy responses fall into four broad categories: carrots, sticks, defenses, and management. *Carrots* include security guarantees and arms control arrangements designed to reassure states that are worried that they might need missiles or unconventional weapons for their defense. *Sticks* include export controls, deterrence through the threat of retaliation, economic sanctions, and the threat of preventive war, all of which are intended to thwart or deter proliferation. *Defenses*, both active and passive, seek to insulate the United States (and possibly its allies) from the effects of proliferation. *Management* refers to measures designed to cope with proliferation in a cooperative fashion by, for example, transferring technology or information that would decrease the probability of accident, misuse, and instability.

SECURITY GUARANTEES

Promising to defend a country if it is attacked can alleviate desires for advanced weaponry, but this strategy has obvious limitations. The U.S. commitment to defend South Korea and Taiwan, not to mention Germany and Japan, may have averted the development of nuclear weapons by each of these nations. It is extremely difficult, however, to identify additional nations among those listed in Table 2 to which the United States could extend security guarantees. Even in the case of moderate Arab states such as Egypt and Saudi Arabia, guarantees would encounter strong opposition from supporters of Israel. Collective security guarantees, in which large groups of nations (e.g., the United Nations) agree to come to the aid of any member under attack, are more appealing, but for most nations collective security does not seem sufficiently reliable to forestall the desire to acquire advanced weapons.

ARMS CONTROL

Chemical, biological, and nuclear weapons have been the subject of multi-lateral arms control treaties; missiles have not. Although arms control treaties cannot prevent proliferation, they can provide a mechanism whereby nations that prefer not to develop certain types of weapons can be reassured that their rivals are also not developing them. If a nation believes that it would be better off if both it *and* its rivals refrained from acquiring certain weapons, then arms control should be an attractive solution. Unfortunately, it is not always so simple. For example, although India might be worse off if both it and Pakistan had ballistic missiles or nuclear weapons, India must face another rival—China—which already has both and shows no interest in giving them up. Moreover, some nations (e.g., Israel) probably believe that they are better off if they possess weapons of mass destruction, even if it means that their rivals are free to develop the same weapons, for otherwise inferiorities in conventional weaponry or manpower could threaten their survival.

The 1925 Geneva Protocol prohibits the use (or, as interpreted by some countries, the first use) of chemical and biological weapons in war, but not the production or stockpiling of such weapons.⁵² Virtually all nations support a verified worldwide ban on chemical weapons, and negotiations on a Chemical Weapons Convention (CWC) are continuing in the multilateral Conference on Disarmament in Geneva.⁵³ Although the widespread commercial uses of chemicals makes a ban notoriously difficult to verify, the verification procedures under consideration are impressive, and it appears that, through a combination of continuous monitoring and on-site inspection, nonproduction by parties to a treaty can be adequately verified.⁵⁴

Although the Bush administration strongly supports the goals of the CWC, it has argued that the United States must retain a small stockpile of chemical weapons for deterrent purposes until all other states capable of manufacturing chemical weapons have joined the treaty. As might be expected, this

⁵² See Utgoff, *The Challenge of Chemical Weapons*, for a review of the history of chemical arms control.

⁵³ On January 11, 1989, 149 countries reaffirmed their commitment to the Geneva Protocol and to a global ban on chemical weapons in the Paris Conference on the Prohibition of Chemical Weapons. Although this may appear to justify some optimism about the near-term prospects for a ban on chemical weapons, one should remember that negotiations to ban chemicals have been continuing off and on for nearly a century, and that the current set of talks began two decades ago.

⁵⁴ For a review of the verification problem, see Karlheinz Lohs, Julian P. Perry-Robinson, and Nikita P. Smidovich, "Verification and Chemical-Warfare Weapons," in Francesco Calogero, Marvin L. Goldberger, and Sergei P. Kapitza, *Verification: Monitoring Disarmament* (Boulder, Colo.: Westview, 1991), pp. 123-148.

position has come under heavy criticism by those who claim that it smacks of the division between the “haves” and the “have nots” that undermined adherence to the nuclear Non-Proliferation Treaty (NPT). The administration claims that this clause will be an incentive for potential holdouts to join the treaty. The administration's argument highlights the main problem with all multilateral arms control: what about states that will not sign the treaty? Since chemical weapons appear to be the main instrument by which some Arab states (e.g., Syria and Iraq) hope to offset the Israeli nuclear arsenal, it is unlikely that chemical weapons will disappear completely any time soon.⁵⁵ Other states with powerfully armed neighbors may draw similar conclusions. There is always the hope that nonsignatories will heed world opinion and observe the taboo on the use of chemicals, but it is wise not to put too much faith in the power of international norms, especially those that have been broken in the recent past. The CWC will not prevent proliferation, but that is too high a standard to set for arms control. The appropriate question is whether the world will be a better place with a treaty than without one; in the case of the CWC, the answer is clearly “yes.”

The development, production, stockpiling, and transfer of biological weapons is banned by the Biological Weapons Convention (BWC) of 1972, but the verification provisions of the BWC are limited. Parties to the BWC agree to cooperate with U.N. investigations, but such investigations must be approved by the Security Council, subject to the veto power of its permanent members. Various confidence-building measures have been adopted at the BWC review conferences, but these measures fall far short of the continuous monitoring and on-site inspections contemplated for the CWC. Since chemical agents are more likely to proliferate, because they are easier to produce and disseminate and their effects are more predictable, the lack of stringent BWC verification may not be worrisome now. But if the CWC makes chemical weapons far more difficult to acquire, then biological weapons may come to be seen as an attractive alternative, and their proliferation may be more of a problem.

In a recent trip to the Middle East, U.S. Secretary of State James Baker reportedly found “a lot of sympathy” among Persian Gulf states for a regional

⁵⁵ The link between Israeli nuclear weapons and Arab development of chemical weapons has been made explicit by Arab leaders on several occasions, including during the Paris Conference on the Prohibition of Chemical Weapons. See, for example, Harry Anderson, “Showdown With Libya,” *Newsweek*, January 16, 1989, p. 16.

ban on weapons of mass destruction, and even found “considerable interest” in the idea in Israel.⁵⁶ Although these discussions are commendable, there is little reason to believe that such an agreement could be achieved without solving the larger political problems in the Middle East, especially the Palestinian problem and the question of the occupied territories. If progress is not made along this front, the connection between Israeli nuclear weapons and Arab chemical (and possibly biological) weapons may create difficulties for the NPT as well as for the CWC. The final NPT review conference is scheduled for 1995, at which time the duration of the NPT will be decided. At least seven potential adversaries of Israel are signatories of the NPT: Egypt, Iran, Iraq, Libya, Saudi Arabia, Syria, and Yemen; Israel is not. All except Saudi Arabia and Yemen are strongly suspected of stockpiling chemical weapons; all but Yemen have acquired or are trying to acquire missiles capable of striking Israel. It is likely that the final NPT review conference will be used as a forum in which this group of countries, perhaps joined by other non-aligned nations, to insist that Israel join the NPT. Indeed, it is not inconceivable that these countries may tie their continued adherence to the NPT, as well as their support for the CWC, to Israeli accession to the NPT (or other equivalent steps). This situation would present the United States with a difficult management problem for which it should be prepared.

EXPORT CONTROLS

Controls on the export of key technologies and materials can slow proliferation, but such controls work much better and engender less resentment if they are coupled with a comprehensive arms control regime. In the NPT, for example, exports to signatories are accompanied by “safeguards” to verify that the exports (e.g., nuclear reactors) are not being used for military purposes. Supplier nations that are party to the NPT must require safeguards on all such exports, even to nations that are not parties to the Treaty.⁵⁷ This coupling between arms control and export controls may be an important reason for the relatively slow pace of nuclear proliferation. Unfortunately,

⁵⁶ Don Oberdorfer, “Mideast Arms Sale Curb Favored; Israel, Arabs Study Regional Ban on *The Washington Post*, March 23, 1991, p. A15.

⁵⁷ NPT signatories can, however, supply technology to nations that have unsafeguarded facilities that were developed indigenously or that were supplied by a nonsignatory. This loophole has allowed several nonsignatories to use the knowledge and experience gained from imports of foreign nuclear technologies to pursue weapon development in indigenously developed facilities. Under domestic laws, however, the United States, Canada, and Sweden require safeguards on all facilities in a country to whom nuclear technologies are exported.

no comparable arrangements yet exist for the control of exports of chemical, biological, and ballistic-missile technology or materials. In general, export controls in these areas have been adopted only after proliferation problems were widely recognized. Even after controls are adopted, competition among suppliers and illegal exports often undermine their effectiveness.

Multilateral export controls were recently extended to missile technology through the Missile Technology Control Regime (MTCR).⁵⁸ Although the MTCR has slowed missile programs in several countries, the regime is “too little, too late.” One important flaw in the MTCR is that several current and potential future exporters of missile technology are not part of the regime, including China, India, Israel, North and South Korea, Taiwan, Brazil, and Argentina. Without the cooperation of all important suppliers, export controls can slow, but cannot stop, proliferation. Another major flaw is that the MTCR allows exports of missile technology for use in civilian applications such as space launch vehicles, even though the same technologies can be used in weapons. Even if the MTCR required safeguards to verify that exports were only being used in civilian applications (which it does not), the knowledge and experience gained would alone be sufficient in many cases to greatly aid military programs. And even if missile technologies were only exported to nations without military programs, sounding rockets and space launch vehicles developed for peaceful uses could quickly and easily be converted into ballistic missiles.

The prospects for export controls on chemical and biological warfare capabilities are not much brighter. The Australia Group, a loosely knit group of 23 countries including the United States, has for some time limited the export to certain countries of selected equipment and chemicals and that can be used in the production of chemical agents, and yet chemical weapons have spread, with key technologies often slipping through the export controls of U.S. allies. The United States recently expanded its export restrictions,⁵⁹ but this will be of little help unless most other supplier nations follow suite. Once

⁵⁸ The MTCR was initially an agreement between the Canada, France, Germany, Italy, Japan, United Kingdom, and the United States to limit the export of missiles capable of delivering a payload of at least 500 kilograms over a range of 300 kilometers, as well as missile systems, subsystems, and technologies that would be required to assemble such weapons. Spain, Belgium, the Netherlands, and Luxembourg have since joined the agreement; Sweden, Norway, and the Soviet Union have approved the MTCR restrictions but have not officially subscribed to the agreement.

⁵⁹ “Fact Sheet on Enhanced Proliferation Control Initiative,” Office of the Press Secretary, The White House, December 13, 1990.

again, a large part of the problem is that many of the chemicals and production techniques required for chemical and biological weapons have legitimate civilian uses.⁶⁰ Many of the items whose export the United States limits are used to make plastics, pharmaceuticals, and fertilizers. Nerve agents, for example, are chemically similar to common organophosphate pesticides. Fermenters can be used to produce pathogens as well as antibiotics. Industrialized nations will find it difficult to deny technologies essential for the production of goods such as pesticides and antibiotics, even to the growing list of countries with a suspected interest in developing chemical or biological weapons; yet it is difficult, if not impossible, to ensure that such exports would not or could not be used for military purposes.

The power of export controls by the industrialized nations is waning. Several Third World countries, such as India and Brazil, have thriving chemical industries of their own, and they are highly unlikely to ever join the Australia Group or similar supplier groups. The only hope of enlisting the cooperation of such states is to embed export restrictions in an arms control framework that makes no distinctions between western and eastern, nuclear and nonnuclear, or industrialized and developing nations. In the case of nuclear weapons, chemical weapons, and ballistic missiles, the United States has been unwilling to go this far.

DETERRENCE, SANCTIONS, AND PREVENTIVE WAR

Deterrence and preventive war represent the dark side nonproliferation policy. Deterrence through threat of retaliation in kind is widely credited with preventing the use of chemical weapons in World War I, as well as the non-use of nuclear weapons since the end of World War II. Some claim that during the 1991 Gulf war, it was the possession of chemical weapons by the United States and the implicit threat to use these weapons that deterred Iraq from using its chemical weapons against allied ground troops, but this is far from obvious. First, Iraq apparently did not stockpile chemical weapons in Kuwait, and could not do so once the air war began destroying its supply lines. Iraqi forces may have used chemicals if they were available. Second, although most high-level officials were careful to say that the United States would consider all options if U.S. troops were attacked with chemical agents,

⁶⁰ Stuart Auerbach, "U.S. to Curb Export of Ingredients in Chemical Weapons," *The Washington Post*, February 27, 1991, p. G1, G3.

others made it clear that the United States would not respond in kind. Indeed, the United States did not even have chemical weapons available for use in the Middle East.

It is theoretically impossible to prove that deterrence works, since it is always possible that the other side had no intention of using that which they were supposedly deterred from using. Only failures of deterrence can be verified. If one has faith in the power of the threat of retaliation in kind, then maintaining chemical arsenals might be better than a CWC that does not enjoy universal adherence. Some states or some leaders may not be deterrable, however. Moreover, the United States can deal militarily with most of the emerging unconventional threats with overwhelming conventional force, thus obviating the need for “in kind” retaliation.

The war against Iraq was a preventive war in the minds of many Americans. A primary goal of the war was to destroy Iraq's potential to make and deliver nuclear, chemical, and biological weapons—to make war now, rather than later, when Iraq might be armed with long-range weapons of mass destruction. The destruction of the Iraqi Osiraq reactor by Israel is another example of a preventive use of force. The use of force, especially on the scale of U.S. actions in Iraq, is clearly limited to the most exceptional circumstances and the most obviously aggressive and nefarious governments. The use of economic sanctions is far more palatable, but sanctions by the United States alone are usually insufficient. Hopefully the United Nations can make more widespread use of sanctions to punish nations that use or threaten to use weapons of mass destruction, thereby deterring others from following the same path.

DEFENSE

Even if arms control and export controls are reasonably effective, weapons of mass destruction will likely be acquired by a handful of determined states. Should the United States and its allies rely on the threat of retaliation to deter the use of such weapons, or should they pursue the development of defensive systems that could render such weapons “impotent and obsolete?” When this question was raised by President Reagan in 1983 in the context of the Soviet nuclear threat, general agreement emerged among defense analysts that the goal of a perfect defense was unattainable, and that the benefits of less-than-perfect defenses were unclear, and might well be negative. The use of Scud missiles in the Persian Gulf War and the apparent success of the

Patriot system in shooting them down⁶¹ has rekindled the debate about the desirability of ballistic missile defenses.⁶² Now that perceptions of a Soviet threat have dimmed, should the United States develop defensive systems capable of shooting down missiles launched by Third World countries? I do not think so.

The Patriot is a ground-launched interceptor initially designed to shoot down aircraft, which has a limited capability to intercept short-range ballistic missiles (which travel at relatively low speeds) in their terminal or reentry phase. Although intercepting faster, longer-range missile warheads is far more challenging (especially at ranges of several thousand kilometers), it should be possible to build a system capable of destroying long-range missile warheads with nonnuclear interceptors in the near future. But a major problem with terminal systems is that they can only defend a limited area (“footprint” or area of coverage). The Patriot system, which has a small footprint, could be successful because the number of targets within range of Iraqi missiles was small. Defending cities from longer-range missiles would not only require a more-sophisticated interceptor, but would require far more interceptor sites to defend all possible targets within range of the missile.

In designing terminal defenses against chemically armed missiles, care must be taken that warhead destruction will be high in the atmosphere. If the agent is released as a fine aerosol at altitudes of a few hundred meters or more, it will be sufficiently diluted by the time the cloud reaches the ground that doses will be inconsequential. If, on the other hand, the high explosive in the chemical warhead is not detonated, the agent may be released as relatively large droplets which rain quickly onto the ground (similar to the way in which agent is released from Soviet chemical warheads).⁶³ The lethal area formed by such a release would, however, be much smaller than that resulting from a successful missile attack.

⁶¹ It is not yet clear how successful the Patriot really was in destroying incoming Scud warheads. Some analysts claim that while the Patriot's fragmentation warhead many have destroyed the Scud missile body, it did detonate the high explosives in the Scud warhead in many cases. Casualties were minimized nevertheless because live warheads were knocked off course, and perhaps because some warheads were concrete dummies. See William Safire, “The Great Scud-Patriot” *New York Times*, March 7, 1991, p. A25.

⁶² See, for example, Harold Brown, “Yes on Patriot, No on SDI,” *The Washington Post*, March 27, 1991, p. A23.

⁶³ Theodore A. Postol, “The Prospects for Successful Air-Defense Against Chemically-armed Tactical Ballistic Missile Attacks on Urban Areas,” March 7, 1991 (unpublished).

Even a highly effective terminal defense is unlikely to destroy more than 90 percent of incoming targets, but if only one nuclear or biological warhead penetrates the defenses of a city, thousands of people will die. Even the penetration of a single chemical warhead could result in hundreds of deaths and generate widespread panic in an unprepared population. Military planners are not likely to be satisfied with a 10 percent probability of penetration, however. Rather, it is probable that the deployment of defenses will only lead to the search for offensive countermeasures (e.g., decoys, chaff, multiple warheads, maneuvering warheads, etc.), triggering an offense-defense arms race that leaves both sides less secure. It was the avoidance of just this sort of situation that led the United States and the Soviet Union to limit strategic missile defenses in the Anti-Ballistic Missile (ABM) Treaty.

Only intercontinental-range missiles could threaten the U.S. homeland (except, possibly, from Cuba). Outside of the five declared nuclear powers, only Israel and India could strike the United States in the near future. However, important U.S. allies, such as the United Kingdom, France, Germany, and Japan, may soon be within range of the missile forces of several countries, and the United States might wish to protect its allies from attack. But space-based systems intended to intercept missiles in their boost-phase, such as the SDI “brilliant pebbles” proposal, will not be able to engage short-range missiles or intermediate-range ballistic missiles that fly slightly depressed trajectories.⁶⁴ Such systems might be able to destroy ICBMs, but their benefits are unclear, given how few countries will possess ICBMs, and given that any country sophisticated enough to develop ICBMs could certainly find other ways to deliver nuclear, chemical, and biological weapons if faced with an effective missile defense. Indeed, cruise missiles—about which SDI-type systems can do very little—may in the not-too-distant future prove to be far more effective delivery systems for emerging nuclear, chemical, and biological arsenals than ballistic missiles. Cruise missiles are extremely difficult to defend against.

Deployment of almost any type of defense against long-range missiles or the transfer of relevant technologies to U.S. allies would violate provisions of the ABM Treaty. Under the ABM Treaty the United States and the Soviet Union are permitted to deploy no more than 100 ground-launched missiles,

⁶⁴ David C. Wright and Lisbeth Gronlund, “Underflying Brilliant Pebbles,” *Arms Control Today*, Vol. 21, No. 4 (May 1991), p. 16.

all at a single, fixed site. Mobile or space-based systems are prohibited, and neither country may transfer ABM technologies to third parties. Any system capable of efficiently destroying intermediate-range missiles would have some capability against strategic missiles, which may violate the Treaty. In contemplating defenses against longer-range Third World missiles, the United States must judge whether the benefits afforded by such a defense would be worth jeopardizing the ABM Treaty and the two decades of U.S.-Soviet arms control efforts that are based upon it. The United States and the Soviet Union could agree to deploy defenses in a cooperative fashion to defend against third-party missiles, but this is highly unlikely in the foreseeable future.

MANAGEMENT

As noted above, Third World missiles and weapons of mass destruction are likely to be far more vulnerable to crisis instability, accidents, and intentional misuse than U.S. and Soviet nuclear arsenals have been. While this is undoubtedly a good reason to avoid proliferation in the first place, additional nations will acquire such weapons despite our best efforts at dissuasion. Should the United States quietly offer to help improve the safety and stability of their weapons? It seems illogical to spend billions of dollars ensuring the safety and security of our own weapons, while doing nothing to ensure the safety and security of weapons that may be pointed at us or our allies. If crisis stability becomes a major problem, the United States could extend warnings or assurances as to missile attack, in hopes of preventing inadvertent launches and deterring preemptive strikes. Such measures might be in the best interest of the United States and the world community in general, but it is extremely difficult for a government to command this degree of flexibility in foreign policy. Moreover, such behavior on our part would be interpreted by other Third World nations as a “wink and a nod” to successful proliferators, and this would inevitably undermine the even more important task of preventing the spread of such weapons to additional states.

Conclusions

Ballistic missile proliferation continues, with several nations seeking ever-longer ranges. It is only a matter of time before cruise-missile technology proliferates in similar fashion. Long-range ballistic missiles armed with conventional warheads do not make military sense. This simple fact seems to

be well understood, since many of these same nations are also actively pursuing nuclear, chemical, and biological weapons. Nuclear weapons are by far the most difficult to acquire; the requisite technologies to produce nuclear materials are expensive and export controls are relatively effective. Chemical weapons are much easier to acquire, and a missile armed with a chemical warhead could kill as many people as dozens or even hundreds of conventionally armed missiles. Biological weapons are more difficult to produce and more unpredictable in their effects, but could inflict casualties on the scale of small nuclear weapons. Therefore, it should not be surprising if the future of missile proliferation points in the direction of chemical and biological weaponry, since for many states they are the only weapons that could constitute a strategic threat or a strategic deterrent.

In dealing with this emerging threat, the United States and its allies should resist calls to develop ballistic missile defenses or to rely on deterrence or threat of military force. Defenses would be costly and imperfect; they would trigger offensive countermeasures and endanger superpower arms control; and they would address only one of ways in which weapons of mass destruction could be delivered (and probably the least likely way they would be delivered to the United States). While deterrence may work among the nuclear powers, it is an unreliable foundation for Third World security, due to the increased probability of accidents, unauthorized use, crisis instability, political instability, and transfers to terrorist or sub-national groups.

The best approach lies in the creation of a comprehensive arms control regime that covers all of these weapons, and which incorporates safeguards to ensure that exports—even to nonsignatories—are used only for peaceful purposes, coupled with the expanded use of the United Nations to foster collective security in the longer term. Comprehensive arms control regimes are unlikely to be created, however, if the superpowers continue to be viewed by Third World nations as “advocating water, but drinking wine.” The superpowers are unlikely to command much authority in their efforts to limit nuclear weapons or ballistic missiles if they continue to develop, test, and deploy new types of nuclear weapons and missiles that they claim are essential for their security. Nor are they likely to muster much support for a “ban” on chemical weapons that permits the superpowers to retain small stockpiles for their own security. Nor are Third World countries likely to support treaties that permit their enemies to possess (or even use) weapons of mass destruction with impunity. The United States should promote the United Nations as the appropriate forum for addressing security and prolif-

eration concerns. In particular, more use should be made of global economic sanctions to punish nations that violate agreed international norms, such as using or threatening to use weapons of mass destruction.

During the Cold War, efforts to stem proliferation often took a back seat to superpower confrontation, as illustrated by the U.S. decision to extend aid to Pakistan in support of *Mujahideen* guerrillas in Afghanistan, rather than cut it off in response to Pakistan's nuclear developments. Perhaps with the end of the Cold War and the Persian Gulf war, the United States and its allies can focus their attention firmly on the proliferation problem. A coherent, self-consistent, and high-priority effort is urgently needed if the United States and its allies are to avert the growing vulnerability of civilian populations to attacks with weapons of mass destruction.