26 JUL 1995

Ref: 95-F-1411

Mr. William M. Arkin
P.O. Box 149
South Pomfret, VT 05067

Dear Mr. Arkin:

This responds to your May 15, 1995, Freedom of Information Act (FOIA) request pertaining to a 1992 report titled *Ballistic Missile Proliferation: An Emerging Threat*. Your letter, addressed to the Ballistic Missile Defense Organization (BMDO), was referred to this Directorate for administrative FOIA processing. We received your letter on June 27, 1995. Our July 3, 1995, interim response refers.

BMDO has provided the enclosed report as responsive to your request. There are no chargeable costs for processing, in this instance.

Sincerely,

SIGNED

A. H. Passarella
Director
Freedom of Information
and Security Review

Enclosure:
As stated

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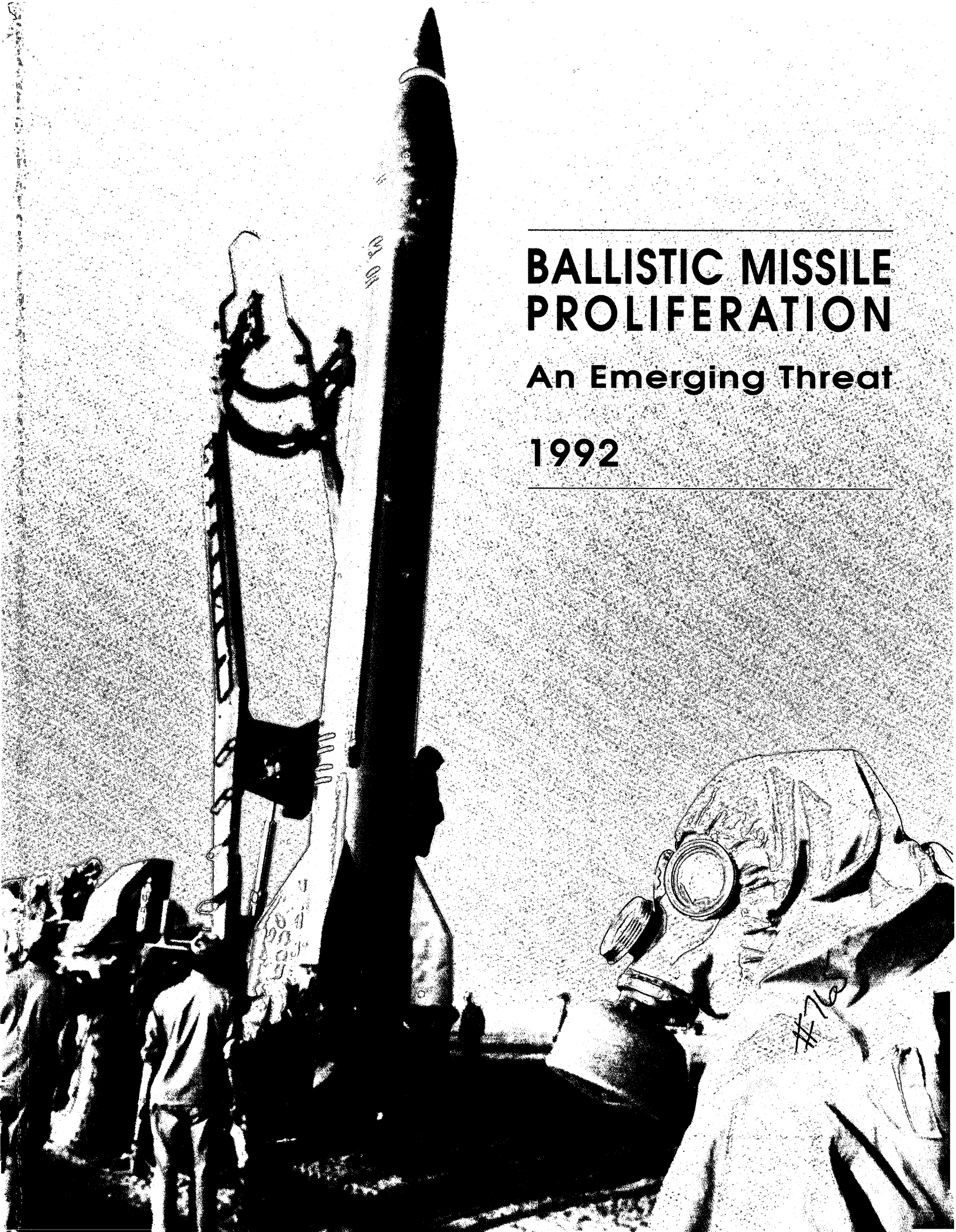

BALLISTIC MISSILE PROLIFERATION

An Emerging Threat

1992

This report was prepared by System Planning Corporation under the direction of Dr. Robert G. Nagler. The views, opinions, or findings contained in this report are those of the authors and should not be construed as an official Department of Defense position, policy, or decision, unless so designated by other official documentation.

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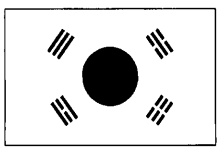
BALLISTIC MISSILE PROLIFERATION

An Emerging Threat

1992



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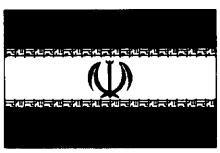

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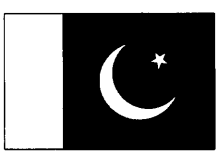

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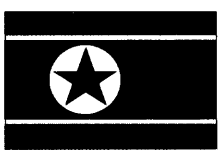

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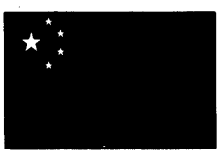

China

Libya

Ambassador Henry F. Cooper
Director
Strategic Defense Initiative Organization
The Pentagon
Washington, D.C. 20301

Dear Mr. Ambassador:

At your request, the Strategic Defense Initiative Advisory Committee has reviewed the report on worldwide ballistic missile proliferation. The Committee believes that this report constitutes a credible portrayal of an existing and growing threat to the national security of the United States, its allies, and other countries. It is imperative that the U.S. respond to this threat with a strong combination of diplomacy, offensive deterrence, and defense against ballistic missile attack.

As the report notes, ballistic missiles have a nearly irresistible appeal for hostile or politically ambitious leaders of many developing countries, and for the governments of nations as a deterrent to aggression. Basic ballistic missile technology has existed for over 50 years, and educated and trained scientists and engineers are sufficiently accessible worldwide that indigenous ballistic missile development capabilities can be acquired by determined countries. Moreover, when these countries offer large sums of money for missile components and technology, their acquisition is a likely possibility. There is no sound basis for assuming that either the pull of demand or the push of supply will diminish appreciably. Nor are the prospects good that either diplomatic efforts to stem the proliferation of missiles or offensive deterrents to their use will, in and of themselves, eliminate the threat of missile attack. Therefore, in the absence of effective defenses, the ballistic missile threat will persist for many decades to come.

If, on the other hand, the U.S., its allies and friends, and even its recent adversaries like the former Soviet Union deploy effective and credible ballistic missile defenses, aggressor nations will find that large expenditures for offensive missiles only diminish their national resources while adding little to their military capability to threaten other countries. Thus, ballistic missile defenses not only will provide *protection* in event of attack, but also may pose a new *deterrent* to proliferation.

We urge that you make this report available to the widest possible audience.

Strategic Defense Initiative Advisory Committee

Dr. William R. Graham, Chairman

Dr. Robert R. Everett	Dr. W. A. Nierenberg
Mr. Daniel J. Fink	Gen. B. A. Schriever (USAF, Ret.)
Dr. O'Dean Judd	Dr. Frederick Seitz
Dr. Hans M. Mark	Dr. Robert L. Sproull
Dr. Richard A. Montgomery	Dr. Edward Teller

October 1992

Preface

A large number and expanding variety of offensive missile systems are found in the military forces of developing nations today. Many are imported, some are indigenous, and a few are ingeniously modified; all are lethal weapons of modern warfare. These missiles already pose a threat to U.S. interests, U.S. forces abroad, and U.S. allies and friends. As the missiles become more sophisticated, that threat will increase significantly, particularly if they are equipped with nuclear, chemical, or biological warheads.

The focus of this report is on missile proliferation in countries other than the United States, its traditional European/NATO allies, and the former Warsaw Pact nations. These developing nations have been referred to by such terms as *Third World, rest of world (ROW),* and *nth countries.* In order to avoid confusion, the term *developing countries* is used in this text.

It is difficult even for the expert to comprehend the scope, complexity, and direction of the missile proliferation threat. Sorting through the plethora of missile names and nomenclatures and learning the different categories and groupings of missiles are challenging tasks. Adding to this challenge is the fact that the missiles and launchers acquired by developing nations may be modified extensively, converted from one mission to another, and used in unconventional ways.

Leaders of developing nations acquire or produce offensive missiles for a number of reasons: to increase their power, prestige, and image; to achieve specific military goals; and to compete economically in the global aerospace or weapon systems marketplace. A major goal of the United States is to halt and reverse missile proliferation.

The United States played a prominent leadership role in creation of the Missile Technology Control Regime (MTCR). The MTCR seeks to establish guidelines and procedures that missile suppliers voluntarily follow to regulate their exports of offensive missiles and key supporting technologies or missile subcomponents. Through the MTCR and related diplomatic and legal endeavors, the United States seeks to stem the flow of advanced missile systems into unstable regions of the world. In fact, based on some recent exchanges, the Commonwealth of Independent States (CIS)—the former Soviet Union—appears to have similar interests.

As the events of the Persian Gulf war so vividly demonstrated, offensive missiles already have been acquired by developing countries. And despite ongoing diplomatic efforts, the threat posed by those missiles may be even more dangerous in the future. National leaders bent upon acquiring modern offensive weapons have a number of sources available. Thus, it is important that the nature of the emerging missile threat be well understood: where U.S. interests are threatened, how they are threatened, and the options for dealing with those threats if diplomacy fails. Deterrence is one option. Defense against the missiles is another.

This report is intended to assist the reader in reaching informed judgments on the issues pertaining to potential responses to the threat of missile proliferation. The scope and trends of that threat, the constraints on and prospects for missile proliferation, and the importance of deterrence and defense are key elements of an informed public appreciation of the emerging missile threat.

The principal focus of this report is on guided ballistic missiles with ranges of 300 km or greater. However, it also provides information related to the aerodynamic, or cruise, missile threat, as well as very short-range ballistic missiles. These missiles play a significant role in the proliferation process and have a military capability that must be defended against. Moreover, defense systems generally have—or can be provided with—some capability of defeating them. Unguided rockets are included in the discussion occasionally for purposes of comparison.

This report was prepared by System Planning Corporation at the direction of the Strategic Defense Initiative Organization. It has been compiled exclusively from unclassified sources. As a consequence, it may contain some factual errors regarding, for example, the precise status of specific countries' missile programs and inventories. Nevertheless, these errors are not believed to affect the principal conclusions.

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Summary

This report, based solely on information available from unclassified sources, provides a coherent picture of the scope and trends of ballistic missile proliferation. The focus is on countries developing, producing, or owning ballistic missiles capable of threatening the military forces, assets, or populations of neighboring or geographically remote countries. The report also identifies other countries expected to obtain operational ballistic missile capabilities, discusses expected growth in performance, and examines the projected availability of warheads of mass destruction. The emphasis is on ballistic missiles of ranges greater than approximately 300 km, though shorter range battlefield weapons are discussed as forerunners. The assessment excludes principal U.S. allies and countries formerly in the Warsaw Pact, except where these countries have sold missiles, technology, or personnel services to developing nations in support of their missile programs.

Ballistic missiles are appealing to leaders of developing countries, often serving as status symbols. Their long range, short flight time, flexible payload, and relatively low cost provide unique political as well as military advantages. In addition, currently available defenses against ballistic missiles are neither truly effective nor widely deployed.

The cold war competition between the former Soviet Union and the United States spawned a missile development race that was followed by missile development some 15 to 20 years later by China (supported by the USSR) and by France and Great Britain (aided by the United States). Now these first- and second-generation missile development cycles are being initiated again—this time in developing countries—after another 20-year delay. However, the wide range of open-market sources for missile components is shortening the development cycles for countries with the money to buy that technology. The Gulf war brought home the threat of missile proliferation with the use, by Iraq, of ballistic missiles.

Jane's Defence Weekly and *The Economist* regularly run popular features summarizing the "hot spots" of the world in terms of ongoing wars, border clashes, and insurrections evolving out of political, ethnic, and religious differences. In this climate, proliferation of missile and warhead technology becomes a major challenge to world peace. Treaties, export controls, diplomatic undertakings, and selective sanctions have been a major focus in limiting the proliferation of weapons of mass destruction and the means to deliver them.

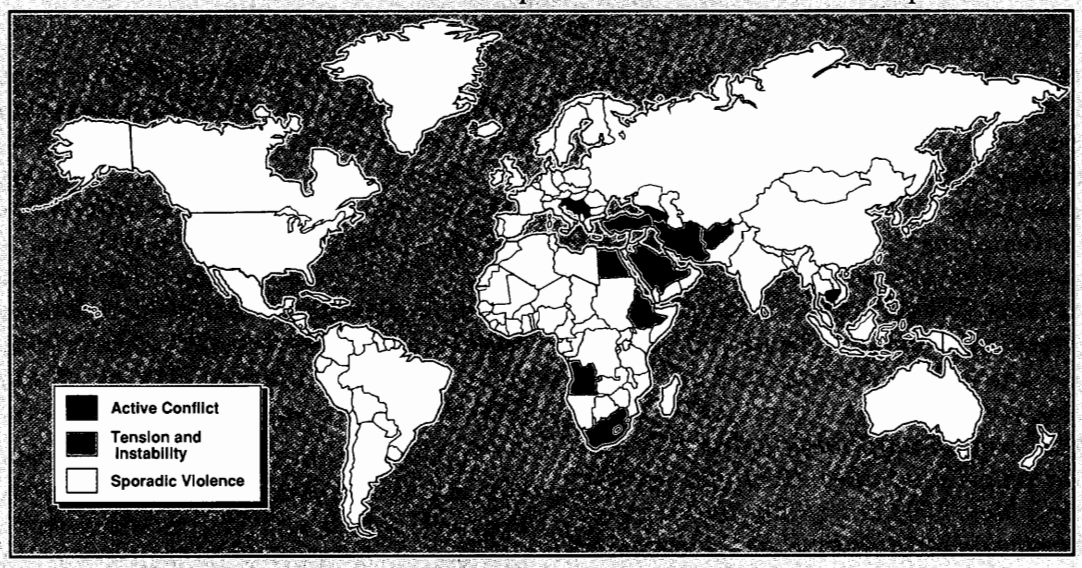
Limits on the use of chemical weapons were addressed after World War I in the 1925 Geneva Protocol, which still stands today with a large number of signatories. Biological warheads were similarly limited by the 1972 Biological Weapons Convention and its signatories. In the 1980s, the Missile Technology Control Regime (MTCR) was established to provide export control agreements among seven leading industrial nations. Since that time, 16 other nations have joined this regime. The MTCR has impeded the progress of proliferation to some extent, but it certainly has not eliminated the ability of a determined leader to obtain advanced weapons. Active and passive defense have thus become a means to reduce the effectiveness of ballistic and cruise missiles. If offensive missiles are not effective, aggressors will have little rationale for acquiring them.

The number of countries possessing longer range (>1,000 km) missiles is expected to increase significantly over the next decade. Thirteen countries have produced, or are in the process of producing, missiles with ranges greater than 300 km. Five of these countries have shown an interest in exporting these longer range missiles. To date, exporters of long-range ballistic missiles include the Soviet Union (Scud B), North Korea (Scuds B and C), and China (M−9, M−11, and CSS−2). Except for the CSS−2, these missiles are of comparable size and are road mobile.

Although missiles operating at more than 300 km are important in terms of strategic and theater warfare, it is the countries with missiles with

World Hot Spots

Four states with active conflict, sixteen with tension and instability, and fifteen with sporadic violence threaten world peace.



ranges under 300 km that are in a position to take the next step—either through development or purchase—into the technology range of 300 km or greater. Countries that buy shorter range missiles can use what they learn from the associated technologies to extend their own indigenous capability to longer ranges. Indeed, the production of only unguided rockets fired from multiple rocket launchers (MRLs) may be the first step in theater ballistic missile proliferation.

The most proliferated guided ballistic missile in the world is the 300-km Soviet Scud, which has been identified in the weapon inventories of 16 countries. This number includes the USSR and six former Warsaw Pact countries. North Korea has reengineered the Soviet Scud B to produce its own Scud B and Scud C and the new No Dong 1 with ranges out to 1,000 km. In turn, North Korea is reported to have licensed manufacturing lines in Egypt, Syria, Iran, and Iraq. Iraq modified Scuds to produce its Al Hussein, Al Abbas, and Al Aabed. China has developed the "M" series of solid-propellant ballistic missiles specifically for sale to other countries. With assistance from China and Europe, Brazil is developing the MB/EE series with similar solid-propellant capabilities. In turn, Brazil, China, and some of the same European countries have been helping Libya with its Al Fatah solid-propellant ballistic missile. Argentina developed a solid-propellant Condor ballistic missile from sounding rocket technology and has sold the technology to Egypt and Iraq, where it is known as the Vector and Badr 2000, respectively. Jericho was developed by Israel and the technology passed to South Africa. Taiwan's Green Bee is a reverse-engineered U.S. Lance, while the NHK series in South Korea is a reverse-engineered U.S. Nike–Hercules. The Pakistani and Indian indigenous missiles were developed with assistance from China and various European countries, respectively. Even the Chinese CSS–2 presently being sold to Saudi Arabia is a reverse-engineered extension of a purchased Soviet SS–3. Everything is linked in some way to nearly everything else.

The proliferation threat will increase in many dimensions: range, accuracy, number of countries, and number of weapons of mass destruction. Modest increases in range (factors of two to three) can be achieved by increasing fuel capacity, reducing payload, or reducing weight in other areas. Major range extensions require new designs.

The present world economy allows developing countries to short-circuit the developmental lag for additional range capability and targeting accu-

racy improvements through free market purchase of components that would normally take years to develop indigenously. The general availability of modern inertial reference components, in-flight location reference updates, and even simple anti-radiation or TV comparator homers has been accelerating this process. Sounding rocket programs in Argentina, Brazil, and Indonesia have aided some ballistic missile developments, while space launch vehicle developments have had a similar positive impact on ballistic missile range capability improvements in China, India, Iraq, Israel, and Pakistan.

Money is obviously a key variable in missile development. The country with a large budget for military expenditures can make or buy missiles with or without the complete array of necessary technologies. All of the major players are among the 43 countries whose average yearly military expenditures over the period 1984–1988 were greater than $2 billion. Countries that exported a great deal of military equipment tended to be those that sold missiles, while those that imported it usually included all countries that were trying to develop an indigenous missile production capability.

All of these missiles should be considered in a regional context rather than individually. It is the regional matchups that really focus missile proliferation. Most of the regional conflicts are cultural or religious and are supported by the availability of oil or drug money or through subsidy from some developed country needing a raw material. Some of the more interesting regions of conflict include the Middle East, North Africa, Asia, and Latin America.

The availability of technology is also key. Despite some constraints on the transfer of missile technology, propulsion systems with a wide range of solid- or liquid-propellant chemistries are essentially state of the art in many developed countries and are thus commercially available. Missile structural design software programs are also available from NASA and a variety of other unclassified sources. Putting these components together requires a machine shop and a welding shop with machines available from other, nonmilitary applications. Inertial reference systems about the size of a fist are readily available with accuracies in the hundreds of meters; in the next few years, completely solid state inertial reference chips are projected with accuracies in the tens of meters. If that is not good enough, the aforementioned radiation homers and TV comparator homers are available commercially if the user can implement a control system to maneuver warheads in the terminal phase. All of these products have been advertised for sale commercially. One factor that may accelerate the growth rate of proliferation and sophistication is the increasing availability of missile design expertise from other countries including the former Soviet Union.

Warhead technologies are also generally available, although nuclear technology is more controlled and requires greater technological resources than chemical or biological weapons. The advantage of nuclear, chemical, and biological warheads over conventional explosive warheads is their area of destruction. Since their destructive reach is generally much greater than their targeting accuracy, the probability of target kill is much higher—as is the probability of producing collateral damage (i.e., damage to the area surrounding the intended target).

Nuclear fission technology has been demonstrated and applied for half a century, and nuclear fusion technology for four decades. Hundreds of commercial nuclear powerplants are in operation. Similarly, hundreds of nuclear reactors are used as the propulsion systems on ships and submarines or for other specialized purposes. And over 50,000 nuclear warheads have been built, deployed, tested, or stockpiled throughout the world.

Proliferation can occur in many forms—transfer of weapons, nuclear material, production equipment, weapon design expertise, basic nuclear technology, or human resources. The major advances in computation capabilities make it realistic to assume that many developing countries could fabricate nuclear weapons, assuming the availability of weapon-grade material. This has been demonstrated repeatedly since 1945. Also, many countries, including Iraq, have shown willingness to make the investment to develop nuclear material processing capabilities. Finally, there is also concern that some weapons can be stolen or sold in secret arrangements, or transferred for ethnic or religious reasons from one country to another.

Among the developing countries, only Egypt, India, Iraq, Israel, and Pakistan are known to possess chemical weapons. However, development and production of such weapons can be accomplished with widely available technical expertise and equipment. Many other countries may be well on the way to possessing chemical weapons.

Limits on the use of chemical weapons have been in effect since the end of World War I. Recent incidents of use, particularly by the Iraqis against minority groups, demonstrate that no ban can be fully effective. Iraq has demonstrated how easy it is to manufacture some of these chemical and biological agents. In 1983, a German chemical company completed a pesticide plant for Iraq. The products of this plant were sent to another plant in Samarra where tabun and sarin were manufactured. This plant reportedly had production lines furnished by German, French, and Soviet suppliers. Also in 1983, Iraq reportedly purchased theodiglycol from a Belgian subsidiary of Phillips Petroleum, using KBS, a Dutch trading company, as a middleman. The addition of hydrochloric acid to theodiglycol creates mustard gas.

Biological warfare involves the deployment of bacteria, viruses, rickettsiae, fungi, protozoa, and toxins from organic matter to produce death or disease in humans, animals, or plants. Livestock is particularly susceptible to a wide range of agents, many of which are specific to cattle, pigs, sheep, goats, horses, or other animals. The diseases can often be passed on to humans in meat products, and wholesale slaughter is often the only means of containing the disease. The development, production, and stockpiling of biological and toxin weapons is banned under the 1972 Biological Weapons Convention, to which 110 countries are signatories.

Biological weapons, particularly those employing toxins, can be produced using available technology but are difficult to make effective. In fact, many constraints against use of biological weapons relate to self-damage. Such concerns may be mitigated in the mind of a ruthless opponent, if long-range delivery systems are available.

Fifteen countries in Asia and North Africa have been identified as having ongoing programs to obtain nuclear weapons. Many of these same countries have chemical and biological weapon programs as well. A number of efforts are under way to control the proliferation of these weapons. However, many of the countries with developing threats in these areas have not signed these restrictive agreements. Others, like Iraq, may have signed with no intent to live up to the agreement.

Aerodynamic missiles have been included in this report because of their importance to proliferation. Sixty-six countries are reported to possess aerodynamic missiles, compared with only 23 with guided ballistic missiles. Cruise missiles are generally less expensive to buy, and the fact that they can be readily placed in canisters makes them particularly easy to maintain and operate in harsh environments. Moreover, most countries with ballistic missiles in their inventories first bought and deployed aerodynamic missiles. Thus, in addition to being formidable weapons in their own right, aerodynamic missiles may be a harbinger of things to come.

Modern air defenses can defeat most aerodynamic missiles. However, the sea-skimming and the high-altitude-cruise/steep-dive varieties present a greater challenge. Cruise missiles also have an advantage in that they almost all have some form of active guidance that allows them to hit specific targets much more accurately than most ballistic missiles. They need no special launch pad stability requirements and can be launched from commercial ships and airplanes just as easily as from military craft. Thus, they lend themselves to surprise attacks. Their exhaust plumes are not generally detected by launch warning systems, and their flight times are usually under 15–30 minutes. As a result, they present a formidable challenge for the air defense system.

Chapter One

Context of Proliferation Concerns

Although missiles are widely regarded as a symbol of late 20th-century advances, modern missile technology can trace an evolutionary path to early gunpowder and incendiary weapons. In many instances, these early weapons may have come from, and were widely used in, what we think of today as developing countries.

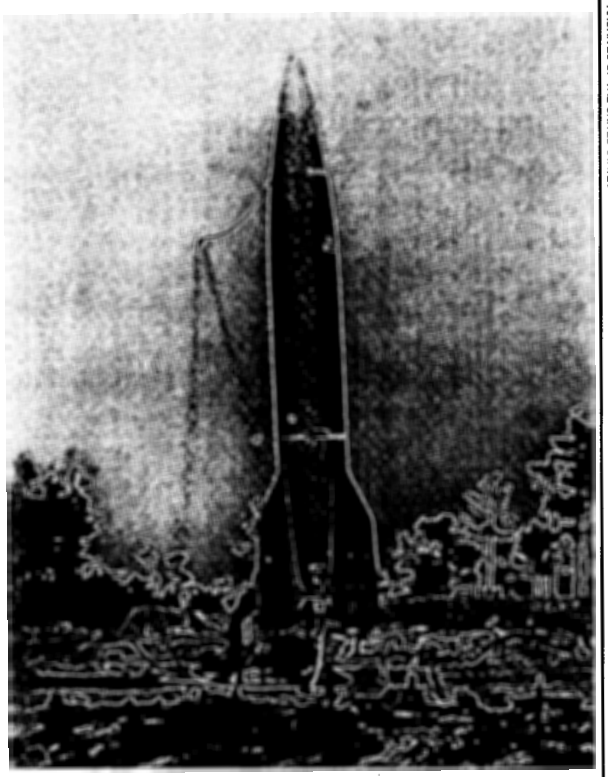
War rockets, initially a form of short-range artillery, probably appeared within decades of the discovery of gunpowder—around the 14th century A.D. Early records are sketchy, but in at least one case—the memoirs of Tamerlane—there is evidence that militaries on the Indian subcontinent were using war rockets by the end of the 1300s. For the next 400 years, war rockets were in widespread use by Chinese, Indian, and Arab armies.

USE OF MISSILES IN MODERN WARFARE

Modern offensive missiles commonly are traced to the German V–1 and V–2 programs of World War II. The V–1 "flying bomb" was a small cruise missile powered by a pulse jet that gave the weapon its characteristic "buzz" sound. Its average range was about 240 km. A primitive but effective weapon, the V–1 caused considerable damage—both physical and psychological—to Britain and other countries against which it was employed. Perhaps the most dramatic single incident was in June 1944, when a single V–1 destroyed the Guard's Chapel at Wellington Barracks, killing 121 people.

During and immediately after World War II, the United States and the Soviet Union used salvaged V–1 parts and captured V–1s in their own cruise missile development programs. The Soviets went beyond the basic V–1 design in developing the Styx family of cruise missiles, which have proliferated in original, duplicate, and improved versions throughout the world. *[Refs. 1, 2, 3]*

The German V–2 was a single-stage, liquid-fueled ballistic missile equipped with an inertial guidance system. The Germans fired it at targets in England up to 350 km away. The V–2 carried a payload consisting of 750 kg of high explosives. Although not an accurate weapon, the V–2 caused considerable damage to urban targets. Unlike the V–1, there was no in-flight defense against the V–2, and therefore it became a more terrifying weapon. *[Refs. 3, 4, 5]*



ARCHIVES OF THE UNITED STATES

German V-2 Rocket

As was the case with the V–1, the United States and the Soviet Union used captured V–2s in the earliest phases of their missile programs. The most proliferated ballistic missile in the world today, the Soviet Scud, is a descendent of the original German designs of World War II.

The V–1 and V–2 were primitive systems by today's military standards. Large, cumbersome, and inaccurate, they were the Model T's of offensive missiles. Yet for all their faults, the V–1 and V–2 were powerful weapons. During the V–weapon campaign, which began in September 1944, more than 25,000 V–weapons were launched against targets in England and areas occupied by the Allies in France, Belgium, and Germany. *[Ref. 3]*

In England alone, V–weapons caused over 30,000 casualties. Winston Churchill described the psychological impact of V–strikes in words that capture the fear of modern urban populations facing the prospect of missile attacks:

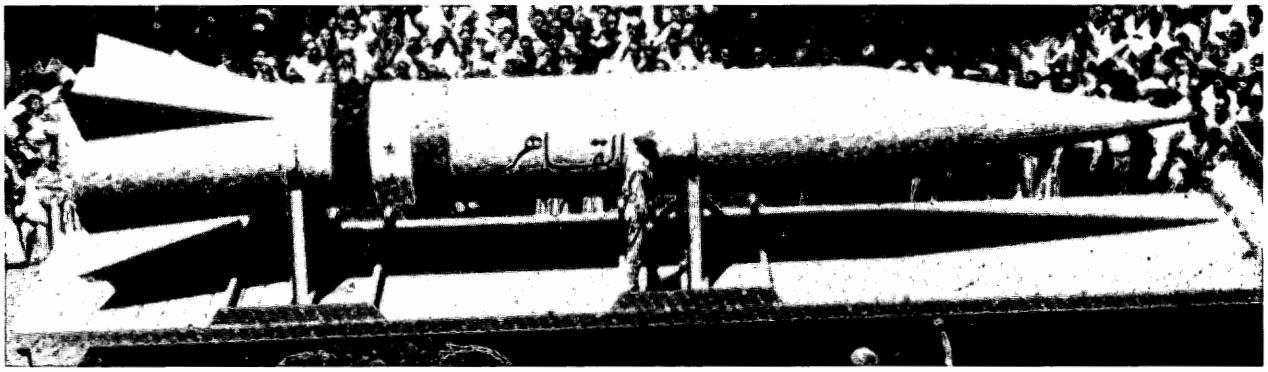
> *[The V-weapons] imposed upon the people of London a burden perhaps even heavier than the air raids of 1940 and 1941. Suspense and strain were more prolonged. . . .The blind impersonal nature of the missile made the individual on the ground feel helpless. [Refs. 3, 6]*

In the late 1950s, Egypt, with extensive assistance from German engineers and technicians, became one of the first developing nations to attempt its own missile development program. A family of liquid-propellant missiles, the Al Zafir and Al Kahir, were operational as early as 1963. These missiles were never used, however, and when German personnel were forced from Egypt, the indigenous Egyptian program withered. *[Refs. 7, 8]*

The Egyptian military has employed several types of modern offensive missiles in combat. In October 1967, Egyptian Komar-class missile boats engaged the Israeli destroyer *Eilat* with Styx antiship cruise missiles at a range of 23 km. Three Styx missiles struck and sank the *Eilat*—the first time a modern warship was sunk by missile fire. In the October 1973 war with Israel, the Egyptian army fired Scud surface-to-surface missiles (which marked the first time Scuds were used in combat), and the Egyptian air force launched air-to-surface AS–5 Kelt missiles. *[Refs. 8, 9, 10]*

If Egypt was the first developing nation to use modern offensive missiles in combat, China has the distinction of being the first developing country to develop and deploy nuclear-armed, long-range ballistic missiles. In 1957, Moscow shipped two SS–2 missiles to China. Chinese engineers copied this system and built, for research purposes, an experimental liquid-fueled rocket; this formed the basis for their follow-on system, the DF–1, which was built and tested between 1960 and 1963. In 1964, the Chinese exploded their first nuclear device, and in October 1967 they tested a nuclear fission weapon on their first operational ballistic missile, the CSS–1 (DF–2). It took the Chinese 7 years from their first flight test of a missile to conduct their first live test of a ballistic missile carrying a nuclear weapon, the CSS–1. *[Refs. 11, 12]*

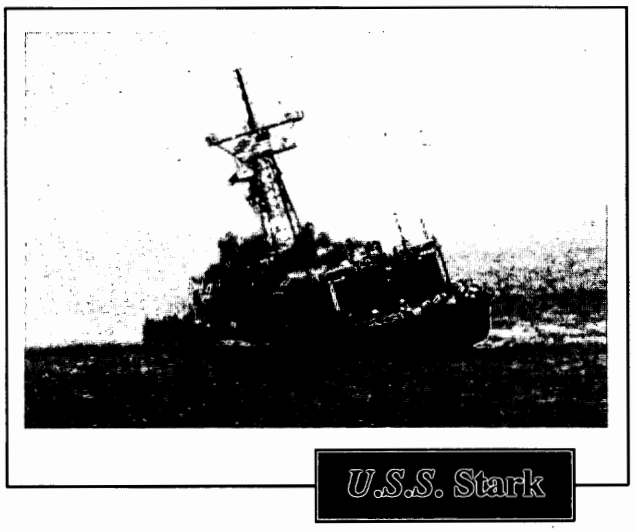
In the 1982 Falklands (Malvinas) war, the Argentines used French-built Exocet missiles against the British forces. The British destroyer H.M.S. *Sheffield* and a British container ship were sunk with Exocets, and another destroyer was damaged. The threat to British forces would have been greater had more Exocets been available to the Argentine military during the war.



JANE'S INFORMATION GROUP

Al Kahir (Egypt)

Today, a large number of developing countries have Exocet-like capabilities in their inventories. An Iraqi fighter heavily damaged the U.S.S. *Stark* with Exocet missiles in 1987. *[Refs. 13, 14, 15]*



Scuds have been used in combat since 1973 by Libya, Iran, Iraq, and Afghanistan. In 1986, following U.S. air strikes on Libya, the Libyan military launched two Scuds at the American Coast Guard facility on the island of Lampedusa, off Italy. The missiles landed in the water about 1.5 km from the facility. In the Iran–Iraq war (1980–1988), over 600 Scuds were fired, including those exchanged during the intensive Scud campaigns in the "war of the cities." In November 1988, the Afghan army displayed Scud B missiles in Kabul and began using them against guerrilla bases. The Afghans reportedly launched over 2,000 Scuds. In the Gulf war, the Iraqis launched about 90 Scuds against targets in Israel, Saudi Arabia, and elsewhere in the region. *[Refs. 13, 16, 17, 18, 19, 20, 21, 22, 23, 24]*

THE DEVELOPING COUNTRIES

The focus of this report is on missile activity in other than NATO and former Warsaw Pact countries. These countries of interest are the developing countries. They include over 120 nations whose differences are as pronounced as their similarities. These nations range from huge continental countries like China to small island states, from the very largest concentrations of the world's population to the very smallest. There is no simple definition for these countries, and neither wealth nor level of industrial development is a reliable index to classification of a country into this category. The oil-rich sheikdoms of the Persian Gulf and the newly industrialized nations on the Pacific rim, for instance, are very wealthy countries. Israel possesses advanced industries, as do Taiwan and other states.

Since 1945, these areas of the world have been the setting for almost ceaseless violence. In many of these regions, a pattern emerges that is reminiscent of state relations in Europe before World War I: continuing suspicions, expensive arms races, official policies that reinforce ancient resentments and fears, and constant jockeying for advantage.

Since the initial wars of independence in the developing nations, there have been some 200 coups, rebellions, civil wars, border clashes, invasions, and extended coalition struggles. At the beginning of 1991, 26 nations considered themselves in some state of war with one or more neighboring states.

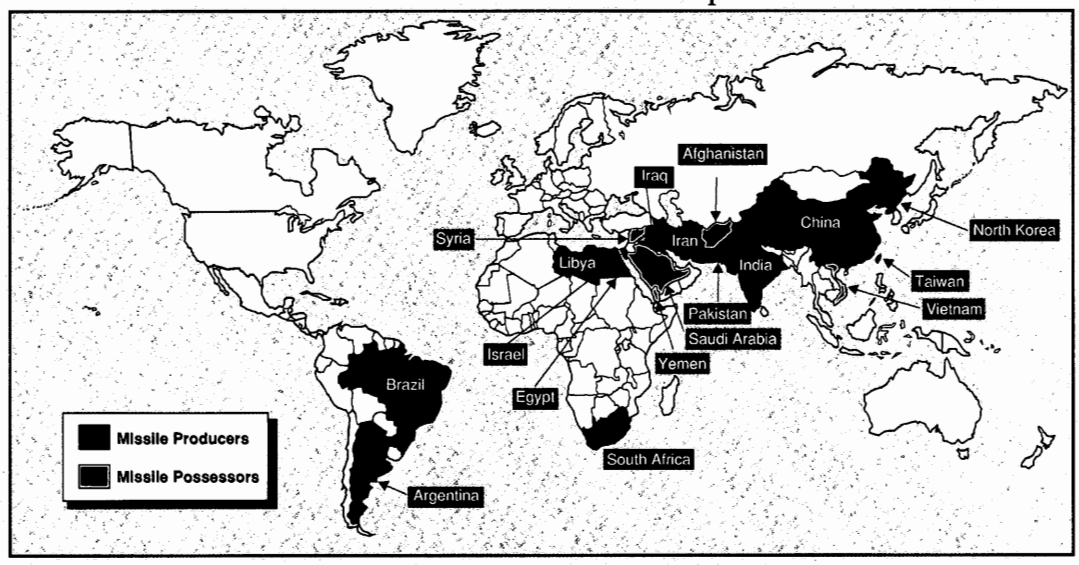
The proliferation threat consists largely of either the short-range (less than 300 km) missiles or the long-range (300–600 km) but relatively inaccurate Scud-derived tactical ballistic missiles. More modern ballistic missiles with extended range and increased accuracy may well enter the inventories of developing countries. That fact, coupled with the regional instabilities that remain after the cold war, suggests the requirement for a fresh look at proliferation in these countries.

PROLIFERATION AS AN ISSUE

In the 1960s, a number of nations agreed to a regime intended to stem the proliferation of nuclear weapons. Nuclear weapons were widely recognized as instruments of mass destruction that, in the hands of aggressors, could expand the scope and violence of smaller conflicts. Chemical and biological weapons were also seen as instruments of mass destruction. The dangers posed by

Developing Nation Missile Producers and Possessors

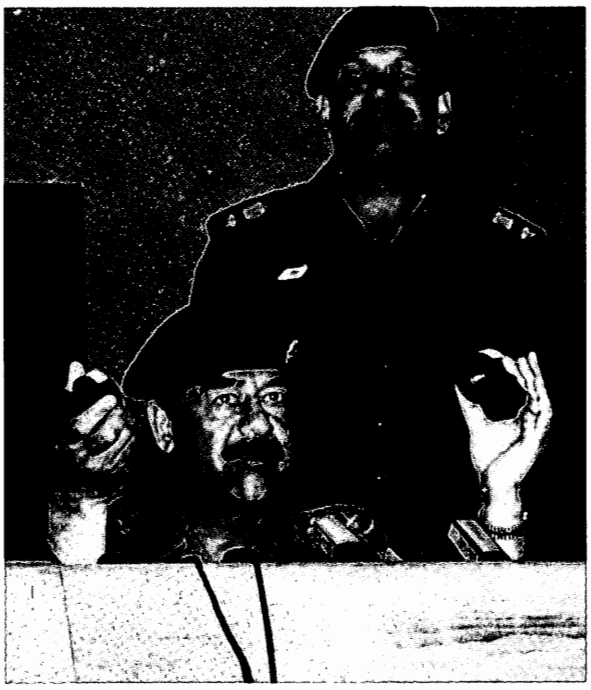
Thirteen countries produce ballistic missiles. Five countries possess but do not produce ballistic missiles.



these weapons are intensified when they are coupled with modern delivery systems.

The coalition victory over Iraq in the Gulf war of 1990–91 vividly underscores the gravity of this threat. Saddam Hussein had invested vast amounts of money to acquire nuclear, chemical, and biological weapons. After the war, U.N. inspection teams uncovered considerable evidence that his investment was already paying deadly returns. For example, the biological warfare research laboratory at Salman Pak near Baghdad had the capacity to produce about 50 gallons of lethal anthrax agent each week—enough to contaminate more than 1,500 square kilometers. Pulmonary anthrax, which induces lesions on the lungs, is almost invariably fatal to humans. Post-conflict inspections reveal that Iraq was closer to a nuclear capability than was generally thought. If Hussein had launched Scud missiles armed with available chemical warheads, widespread disruption would probably have resulted. *[Refs. 25, 26]*

The proliferation problem poses the threat that minor conflicts will become broader in scope and more dangerous than they have been in the past. This is one of the major challenges to U.S. security in the 1990s.



SIPA PRESS

Saddam Hussein Displays Missile Components

There are several dimensions to the proliferation problem. The first concerns proliferation of weapons of mass destruction—nuclear, chemical, or biological weapons. Here, the United States has sought nonproliferation regimes based on a combination of treaties, export controls, diplomatic undertakings, and selective sanctions for violators. The United States was instrumental, for instance, in the diplomacy leading to adoption of the Nuclear Non-Proliferation Treaty, signed at Mexico City in 1968. The United States is party to the 1925 Geneva Protocol on chemical warfare and the 1972 Biological Weapons Convention, and has exerted leadership and influence in the ongoing negotiations for a new, more comprehensive chemical arms treaty.

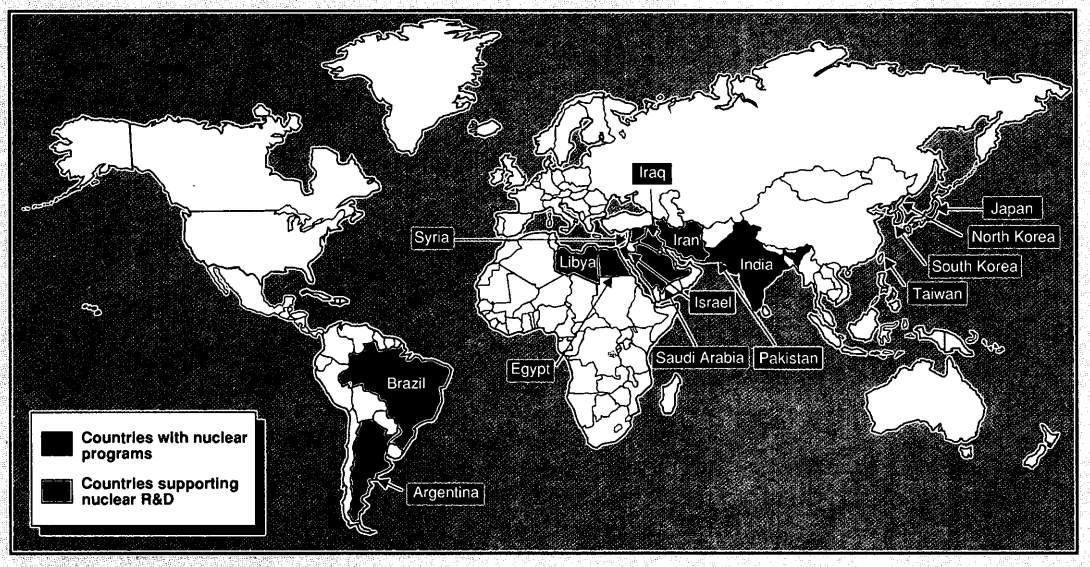
A second dimension concerns proliferation of advanced means of delivery, such as ballistic missiles. The Coordinating Committee on Multilateral Export Controls (CoCom)—established during the cold war years by NATO member states, Japan, and Australia—was an early attempt at controlling such advanced technology. CoCom has historically focused its attention on curbing the export of sensitive goods and technology to Eastern block states. Since the recent events in Eastern Europe and the Soviet Union, CoCom is beginning to redirect its efforts toward control of developing weapon proliferators. However, the effectiveness of CoCom is somewhat limited since compliance with its restrictions is voluntary and the member countries are responsible for the verification and enforcement mechanisms. This has led to conflicts resulting in an uneven application of export restrictions.

In 1985 and 1986, the United States led the effort to create the Missile Technology Control Regime (MTCR), an export control agreement between the seven leading industrial nations of the world. The MTCR includes guidelines addressing the conditions under which exports might occur, a list of controlled technologies, and an informal information-sharing mechanism among the partners. The MTCR was formally announced in 1987. Since then, the United States has worked hard to get other major nations to coordinate their missile export policies with the guidelines of the MTCR.

Unlike the cases with nuclear, chemical, and biological weapons, there are no treaties in existence or under active negotiation governing missile exports, except the bilateral restrictions to which the United States and Soviet Union agreed

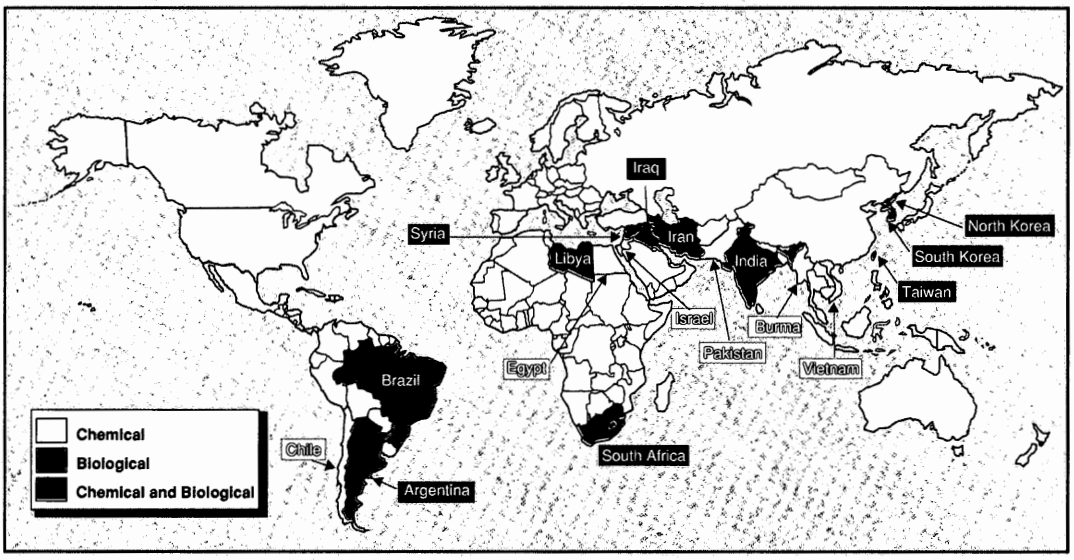
Nuclear Proliferation

Among the developing countries, three have nuclear programs and twelve support nuclear R&D.



Chemical and Biological Weapon Proliferation

Among the developing countries, six have chemical weapons programs, two have biological weapons programs, and nine have both.



in the Intermediate-Range Nuclear Forces (INF) agreement, and have pending in the Strategic Arms Reduction Treaty (START).

Despite the nonproliferation regimes created by treaties, export controls, and diplomatic arrangements, a determined aggressor can acquire advanced weapons, as Saddam Hussein so clearly demonstrated. *[Refs. 27, 28]*

The worldwide proliferation of ballistic missile technology has caused the United States to recognize, even while pursuing measures to strengthen and tighten the nonproliferation regimes, the importance of defenses against offensive missiles, especially longer range missiles that can be armed with warheads that cause mass destruction.

Chapter Two

Ballistic Missiles

More than 30 types of guided ballistic missiles with ranges of 30 km or greater are either operational or under development in 19 developing nations. It is difficult if not impossible to estimate the total size of the missile arsenals in the world today, but the number is considerable.

Ballistic missiles can be launched from fixed launchers on or below the earth's surface, rail-/road-mobile ground launchers, or ships or submarines at sea. Treaties such as the INF Treaty limit the types and deployment conditions of U.S. and Soviet medium- and intermediate-range ballistic missiles (i.e., those with ranges greater than 500 km and less than 5,500 km). However, those treaties do not govern other nations, including large numbers of developing countries acquiring ballistic missile forces. There are over a dozen families of ballistic missiles in developing countries. These are discussed by country in this chapter. Missiles of the USSR and the United States are discussed to the extent that they have been furnished to developing nations.

JANE'S INFORMATION GROUP

Scud B (USSR)

DEVELOPED NATIONS

USSR

The Scud A (SS–1B), designated the R–11 by the Soviets, was developed in the early 1950s by the Korolyev Design Bureau. It took the Soviets about 10 years to develop and field the first operational version. The Scud A could deliver payloads to a range of 180 km with an accuracy of 3,000 m. *[Ref. 23]*

The Scud B (SS–1C, designated the R–17 by the Soviets) was operational in the USSR in 1962. It is capable of delivering payloads to a range of 300 km with a CEP of 450 m. The Scud B has been outfitted at one time or another with conventional, chemical, or nuclear warheads plus a wide variety of submunitions. *[Ref. 23]*

The Scud family of missiles has been deployed with the Warsaw Pact forces for many years, the latest Scud B version dating from 1965. There have been unconfirmed reports that the Soviet Union has developed Scud C and D versions: the Scud C with a maximum range of 550 km and a warhead separating in flight, and the Scud D with a range of under 300 km and terminal guidance. *[Ref. 23]*

The Scud B is a short-range, road-mobile, liquid-propellant, single-warhead ballistic missile. It is 11.25 m long and 0.88 m in diameter. It has a launch weight of 6,370 kg with a range capability of 300 km. Propulsion is by a single-stage liquid motor, and guidance is inertial. The Scud B is carried on an eight-wheeled MAZ–543–P

Note: Much of the material in this chapter is from Reference 27, *Jane's Strategic Weapon Systems,* D. Lennox, ed., 1990.

Ballistic Missiles of Developing Countries

Country	Range Category (km)					Supplier
	30–250	300	500–650	900–1,200	≥1,500	
Afghanistan*		Scud B				USSR
Argentina	Alacran			Condor 2		Indigenous
Brazil	MB/EE–150 SS–150	MB/EE–300 SS–300	MB/EE–600	MB/EE–1000 SS–1000		Indigenous Indigenous
China	B–610	M–11	M–9	M–?	CSS–2	Indigenous
Egypt		Scud B Scud B	Scud C	Vector		USSR North Korea franchise Indigenous (Condor technology)
India	Prithvi				Agni	Indigenous
Iran	Iran–130	Scud B Scud B	Scud C			USSR North Korea franchise Indigenous
Iraq		Scud B Scud B	Scud C Al Hussein	Al Abbas Badr 2000	Al Aabed	USSR North Korea franchise Indigenous (Scud technology) Indigenous (Condor technology)
Israel	Lance		Jericho 1		Jericho 2	Indigenous United States
Libya	SS–21	Scud B	Scud C M–9	Al Fatah		USSR North Korea China Indigenous
North Korea		Scud B	Scud C	No Dong 1	No Dong 2	Indigenous
Pakistan	Hatf 1	M–11 Hatf 2				China Indigenous
Saudi Arabia*					CSS–2	China
South Africa			Arniston			Indigenous (Jericho 1 technology)
South Korea	NHK–1, –2 Lance	NHK–A				Indigenous United States
Syria*	SS–21	Scud B Scud B	Scud C M–9			USSR North Korea China
Taiwan	Green Bee			Sky Horse		Indigenous
Vietnam*		Scud B				USSR
Yemen*	SS–21	Scud B				USSR

*Since these five countries have no indigenous ballistic missile program, they are not further addressed in this chapter.

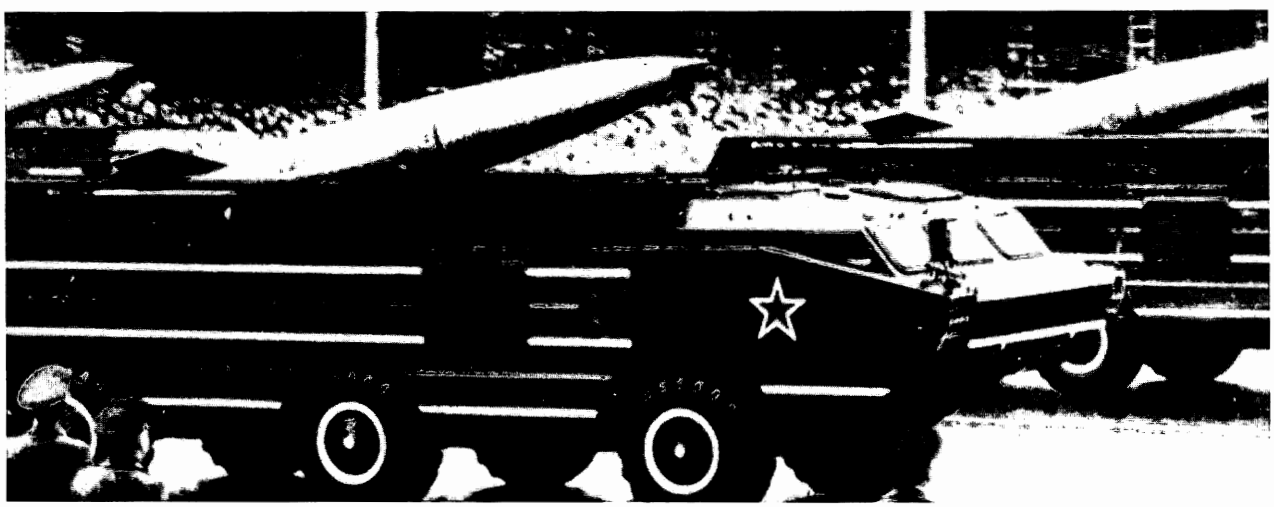
transporter-erector-launcher (TEL) vehicle, and the missile is raised to the vertical position at the back of the TEL prior to launch. After launch, the TEL moves to a new position to evade a counterattack and is reloaded from a towed resupply trailer. *[Ref. 23]*

The Scud B is the most common long-range tactical ballistic missile in the world. It currently resides in the militaries of Afghanistan, Egypt, Iran, Iraq, Libya, North Korea, Syria, Vietnam, and Yemen. The Soviet Union has probably produced between 5,000 and 10,000 Scuds. It is not known how many of these were transferred to its former allies in the Warsaw Pact or how many were exported. Attempts to estimate Scud inventories are further complicated by the fact that nations like North Korea also produce and export their own versions of the Scud. Production lines built in the vicinity of Pyongyang in 1987 reportedly can turn out more than 50 Scud Bs per year. *[Ref. 29]*

Several nations have modified Scuds themselves. The Iraqi Al Hussein and Al Abbas missiles are Scud variants that have been modified for longer range. The Al Hussein has been credited with the capability to deliver a 500-kg payload to a range of 650 km with a CEP of 1,000 m; and the Al Abbas, a 300-kg payload to a range of 900 km with a CEP of 1,500 m. North Korea reportedly produced its own copy of the Scud B by 1988, modified Scud Bs in 1989 to double the range to 600 km, and is building a new missile based on the Scud, called the No Dong, whose range may reach 1,000 km. The Libyans may be assisting North Korea financially in these Scud modification programs. *[Refs. 23, 29, 30, 31]*

The SS–21 (Scarab) is a single-stage, short-range, road-mobile, solid-fueled missile that incorporates an inertial guidance system with inflight updates or terminal guidance for improved accuracy. The Soviet designation for the SS–21 is OTR–21, and its name is Tochka (Point). The SS–21 was developed as the replacement for the short-range unguided FROG missile and was introduced into service in 1976. A number of former Warsaw Pact nations have the SS–21 in their inventories, and it has been exported to Syria, Yemen, and possibly Libya. *[Refs. 28, 32]*

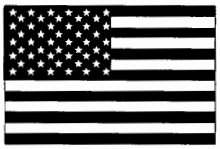
The SS–21 is 6.2 m long and 0.65 m in diameter. It has a launch weight of 2,700 kg and a range of 120 km, with a CEP of about 30 m. Propulsion is a single-stage solid booster and a combined guidance system, with inflight update or terminally guided warhead or submunitions, according to the USSR. The missile can be equipped with improved conventional munitions or chemical or nuclear warheads. The missile is carried on a six-wheeled modified ZIL–5937 TEL vehicle, and it is believed that the associated transloader vehicle carries three additional missiles. *[Ref. 32]*



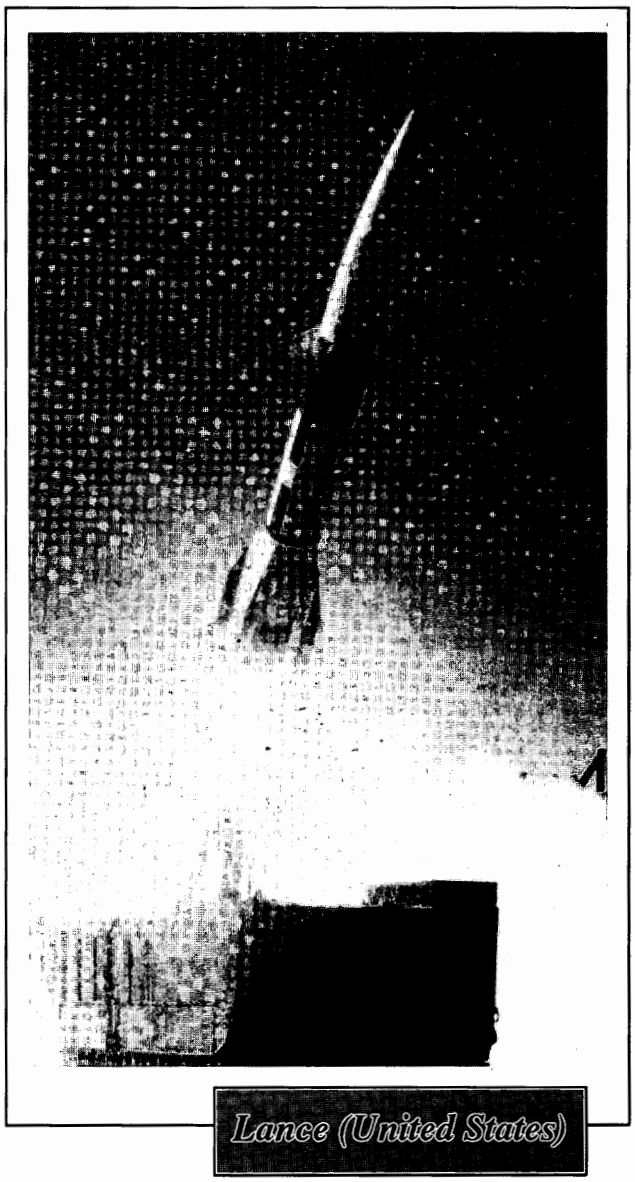
JANE'S INFORMATION GROUP

SS-21 (USSR)

United States



The Lance (MGM–52) was developed to replace the Honest John and Sargeant. It is a short-range, single-stage, liquid-propellant, single-warhead ballistic missile that can deliver its payload to a range of 130 km. The missile is 6.41 m long and 0.56 m in diameter. It has a launch weight of 1,527 kg. The Lance entered service in 1972, and production ended in 1980. The missile uses a simplified inertial guidance system. It is spin stabilized in flight to improve accuracy. The warhead can be either conventional or nuclear. The missile is deployed on an M–752 TEL, with two reloads carried on a second vehicle. Lance missiles have been sold to NATO countries as well as Israel and South Korea. Lance missiles are being deactivated in NATO countries as an arms reduction measure. In addition, the development of a follow-on system was canceled by the United States in 1990. *[Ref. 32]*



Lance (United States)

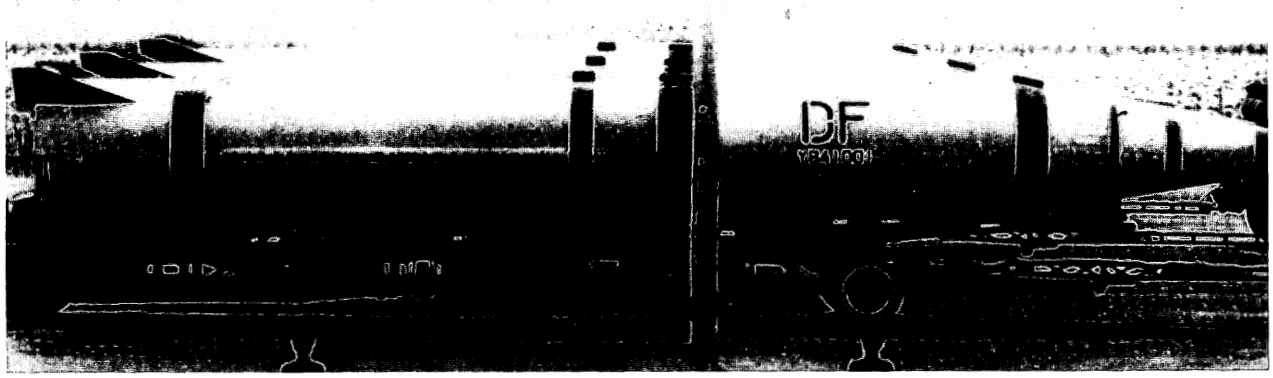
DEVELOPING COUNTRIES

China

In 1958, the Soviets shipped two missiles to China. Working with those systems and with notes and drawings of the Soviet missile, the Chinese developed a prototype of their CSS–1 (DF–2), which was successfully flight-tested in 1964. The CSS–1 is a liquid-fueled, intermediate-range ballistic missile similar to the Soviet SS–3 (Shyster). It is a single-stage, transportable missile, 21 m long and 1.6 m in diameter, with four delta fins at the base. Its launch weight is 26,000 kg, and its maximum range is 1,200 km. The CSS–1 was first deployed in about 1970. *[Ref. 33]*

A second missile in the series is the CSS–2 (DF–3). It was developed in the 1960s and underwent flight testing in 1968. This missile is compatible with both a nuclear and a conventional warhead. It is a single-stage, inertially guided ballistic missile, 20.62 m in length and 2.46 m in diameter, with four delta fins at the base. It weighs 27,000 kg at liftoff and has a range capability of 3,000 km with a CEP of 1,000 m. A modernized version was developed in 1986 with three 100-kt warhead reentry vehicles (RVs) that can be guided to separate targets. It has been reported that between 30 and 50 of the extant Chinese CSS–2s have been purchased by Saudi Arabia. The nuclear payloads have been replaced by conventional high-explosive (HE) warheads, and the effective range was reported to be reduced to 2,700 km. *[Ref. 33]*

The Chinese have developed two longer range missiles, the CSS–3 (DF–4) and the CSS–4 (DF–5). These are two-stage, liquid-propelled missiles with ranges of 7,000 km and 10,000 km, respectively. Both carry warheads in the 1- to 5-Mt range. *[Ref. 12]*

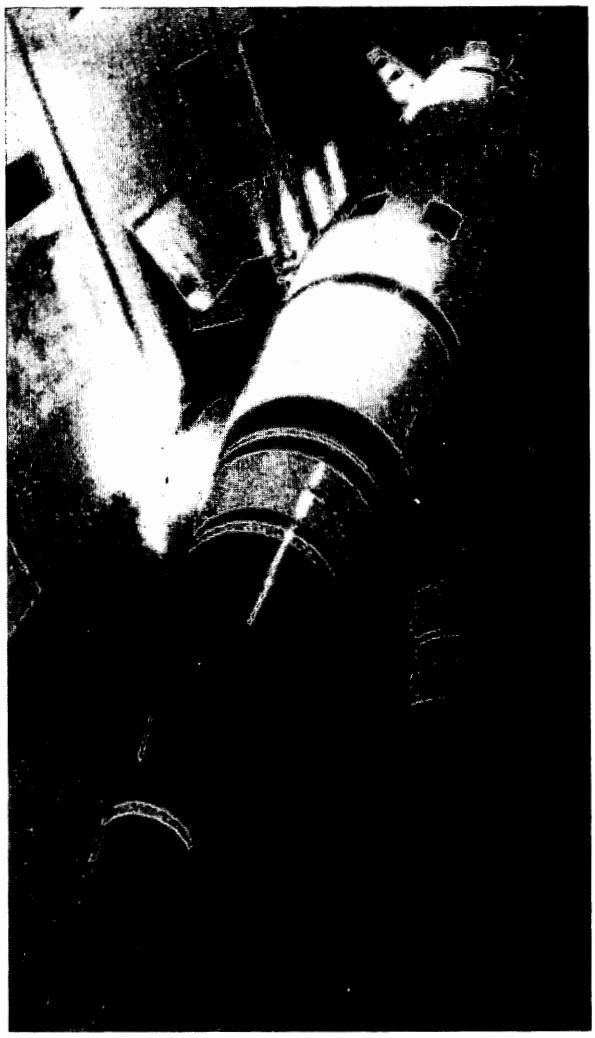


JANE'S INFORMATION GROUP

CSS-2 (China)

The Chinese have also developed the "M" family of ballistic missiles, which includes the M–9, M–11, and possibly an M–7, M–8, M–12, or M–18. They all use solid propellants; the M–9 is a single-stage missile, and the M–11 is a two-stage missile. The M–9 is reported to be 9.1 m long with a body diameter of 1.0 m and a launch weight of 6,200 kg. The missiles are transported on an eight-by-eight wheeled TEL vehicle and are erected to the vertical for launching. The M–9 is believed to use inertial guidance and have a range of 600 km. An accuracy of 300 m has also been reported. Photographs of both the M–11 and M–18 have been released showing a missile and a TEL similar to the M–9. It is believed that the M–11 has a range of 300 km. One of the other M–series missiles reported to have recently been sold has a range of 1,000 km. *[Ref. 33]*

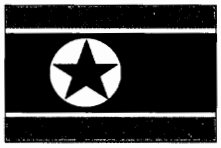
M–11 launchers and training vehicles reportedly have been delivered to Pakistan. There are also reports that Syria was negotiating the purchase of M–9 missiles early in 1988 in place of the Soviet SS–23 banned by the INF Treaty; other reports indicate that Libya was to have purchased 140 M–9s in 1989 and then passed on 80 of these to Syria. The deal apparently was not completed. Syria is alleged to have received some 24 M–9 TELs by late 1991, but the role of Libya in the transfer and delivery of any M–9 missiles is uncertain. *[Refs. 32, 34, 35, 36]*



JANE'S INFORMATION GROUP

M-9 (China)

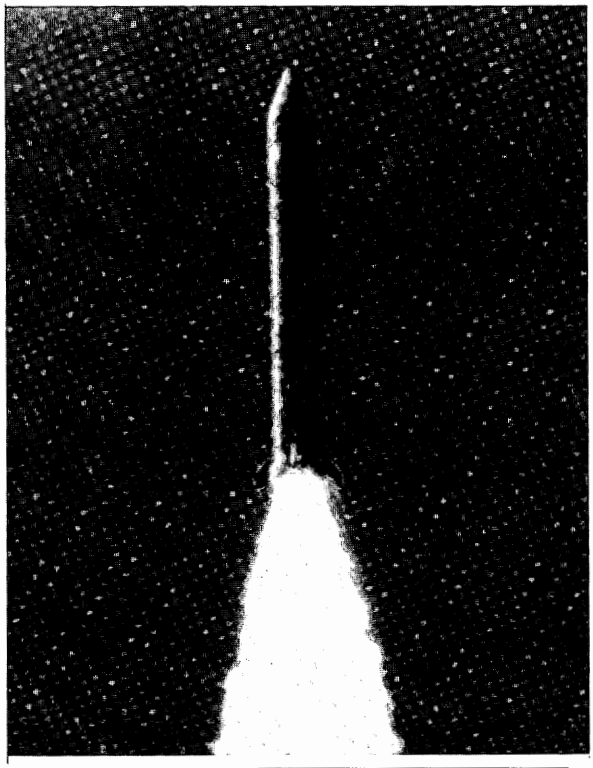
North Korea



North Korea has been producing ballistic missiles since about 1987 when Scud B production lines at Pyongyang were built. This activity was apparently franchised by the USSR. North Korea has, in turn, licensed manufacturing lines to Egypt, Syria, Iran, and Iraq in addition to exporting their own Scud Bs. North Korea has also developed the No Dong 1, a missile having a range of 1,000 km. It has been reported that a longer range (2,000 km) No Dong has been offered for sale. With a fairly meager product line, North Korea has become a major exporter of ballistic missiles. *[Refs. 32, 44, 45, 48]*

Israel

Israel has a well-developed space industry that provides the foundation for its military ballistic missile program. The Israelis embarked on their missile program in the mid 1960s with assistance from France.



JANE'S INFORMATION GROUP

Jericho (Israel)

The Jericho 1 is a short-range, road-mobile, solid-propellant, single-warhead ballistic missile. It is 10.0 m long and has a diameter of 1.2 m with a launch weight of 4,500 kg. This missile has been described as being similar to the Pershing I in terms of size and performance. The warhead can be conventional or chemical; guidance is inertial, and its maximum range is 500 km. It is believed that the Jericho 1 entered service in 1973. Jericho 1 technology may have been transferred to South Africa. *[Ref. 32]*

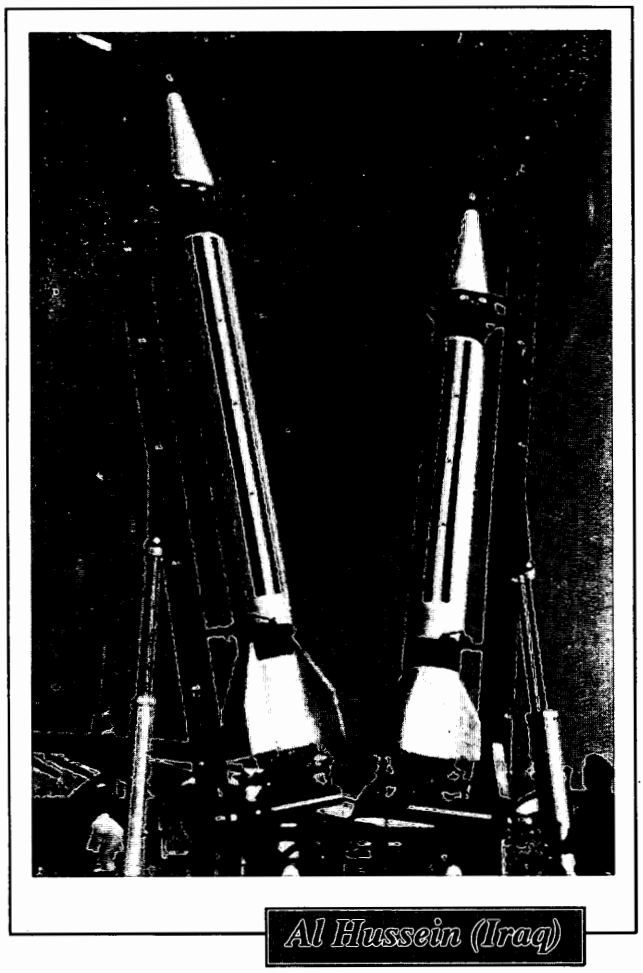
The Jericho 2 is a two-stage, intermediate-range missile. It is believed to be 12.0 m long with a diameter of 1.2 m and a launch weight of 6,500 kg. The payload capability is probably 1,000 kg, and the range is 1,500 km. The guidance again is inertial, and the warhead is either conventional or nuclear. The Jericho 2 is reported to be road mobile. *[Ref. 32]*

Iraq

Iraq has a major indigenous program to extend the range of the Scud Bs that it has acquired from the Soviet Union and the Scud B and C derivatives provided by North Korea. The 650-km Al Hussein was used first in the Iran–Iraq war in 1988 and later in the Persian Gulf war in 1991. Al Abbas, with a range of 900 km, apparently has not seen action. Al Aabed is credited with a range of 2,000 km. The first stage was tested as part of Tamouz 1 satellite launcher tests in 1989.

The Al Hussein is a short-range, road-mobile, liquid-propellant, single-warhead missile. According to Iraq, it is a newly designed and developed system; other reports suggest that it is a modification of the Soviet-developed Scud B. It is reported that the Al Hussein is 12.2 m long, has a diameter of 0.88 m, and weighs 7,000 kg. The payload weight is estimated to be about 500 kg. Inertial guidance is probable. The missile is mounted on an Al Waleen eight-wheeled TEL vehicle. The Al Hussein was used during the Iran–Iraq war during the early months of 1988. *[Refs. 23, 38]*

The Al Abbas appears to be a further development of the Al Hussein. Modifications include an increase in the length of the propellant tanks, a reduction in the warhead weight to 300 kg, and a concomitant increase in range to 900 km. Al Abbas is probably 13.75 m long with a body diame-

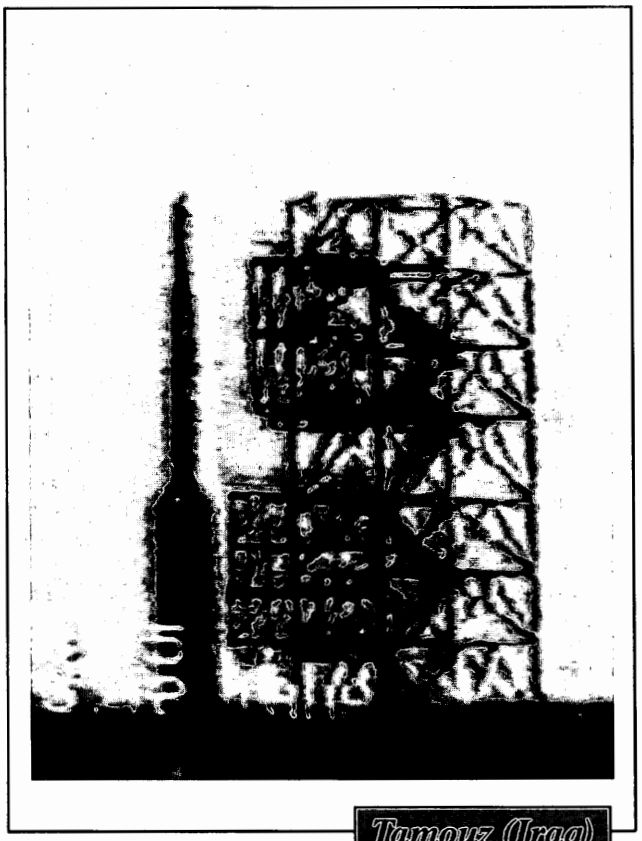


Al Hussein (Iraq)

ter of 0.88 m and a launch weight of 8,000 kg. It is believed that the Al Abbas missile can be carried by the same eight-wheeled Al Waleen TEL used for the Al Hussein. The Al Abbas is not known to have been used during the Iran–Iraq war or the Persian Gulf conflict. *[Refs. 38, 39]*

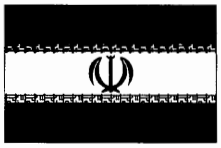
Little is known of the specifications of the Al Aabed intermediate-range missile, but it is believed that it shares stages with the Tamouz 1 space launch vehicle. It is further believed that it incorporates five Al Abbas motors as a first stage, a single Al Abbas motor as a second stage, and an unidentified third stage. From this information, it is concluded that the Al Aabed is 23 m long, has a first-stage diameter of 2.3 m and a second-stage diameter of 0.9 m, has a launch weight of about 48,000 kg, and carries a single warhead of 750 kg. The range is estimated to be about 2,000 km. It was believed that the missile could have entered service around 1995. Under the terms of the United Nations cease-fire agreement ending the Persian Gulf war, Iraq was required to destroy all of its ballistic missiles and weapons of mass destruction. The degree of compliance to date is uncertain. *[Refs. 32, 39]*

Iraq was also an original participant (with Egypt and others) in Argentina's Condor 2 program, an effort to develop a 1,000-km-range ballistic missile. Iraq later dropped out of the consortium, but they were able to retain some of the Condor 2 technology. Reference is occasionally made to an Iraqi program to continue the Condor 2 development as an indigenously produced missile known as Badr 2000. *[Ref. 32]*



Tamouz (Iraq)

Iran



With considerable foreign assistance, much reportedly provided by China, Iran has undertaken indigenous programs to produce ballistic missiles. The Iran–130 (or Nazeat) may have entered service in 1990. The Iranians also reportedly have under development a Shahin 2 missile.

The Iran–130 is a short-range, road-mobile, solid-propellant, single-warhead ballistic missile. The Iranians claim that it is entirely of their own design. The range capability of the missile is reported to be 130 km, but the remaining specifications are unknown. *[Ref. 40]*

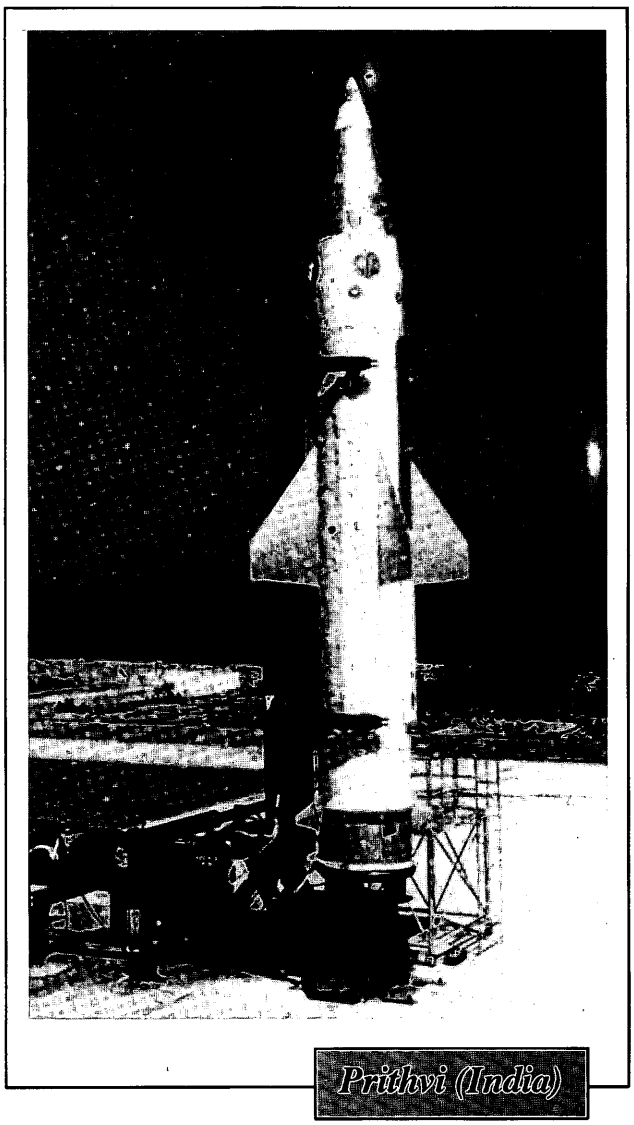
Iran is reported to have acquired Soviet Scud Bs, and information indicates that North Korea is helping Iran establish a Scud B manufacturing line based on the North Korean variant. North Korea is also reported to have sold Scud Bs and Cs to Iran, but numbers are not available. *[Refs. 32, 41, 42]*

India

India has developed one of the most extensive space industries among the developing countries. This industry provides the basis for India's military ballistic missile programs. Two ballistic missiles reportedly are under development in India: the Prithvi and the Agni.

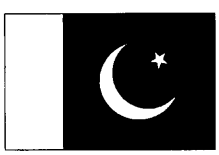
The Prithvi is a short-range, ground-launched, single-stage, liquid-propellant, single-warhead ballistic missile. It was first tested in 1988. The design work may have been done with assistance from other countries, and there are unconfirmed reports of European company participation. It is believed that the missile is 10.0 m long and has a body diameter of 1.1 m. There are four clipped delta wings at midbody. The missile has a maximum range of about 250 km. The launch weight is believed to be 4,000 kg, and a payload of 1,000 kg has been reported. An inertial guidance system is used. Conventional payloads reportedly under development include HE warheads, cluster munitions, and possible fuel-air explosives. The missile will be mounted on an eight-wheeled Kolos Tatra truck and raised to the vertical for launch. *[Refs. 32, 45]*

The Agni is an intermediate-range, single-warhead ballistic missile. It is a two- or three-stage design with a solid propellant in the first stage and a liquid propellant in the second (and third) stage. It has a total length of 18.4 m, a base body diameter of 1.3 m, and an estimated launch weight of 14,000 kg. The payload is reported to be 1,000 kg. The missile is inertially guided and has an estimated range of 2,500 km. The Indian government describes Agni as a technology demonstrator rather than a developed weapon system. *[Refs. 32, 46]*

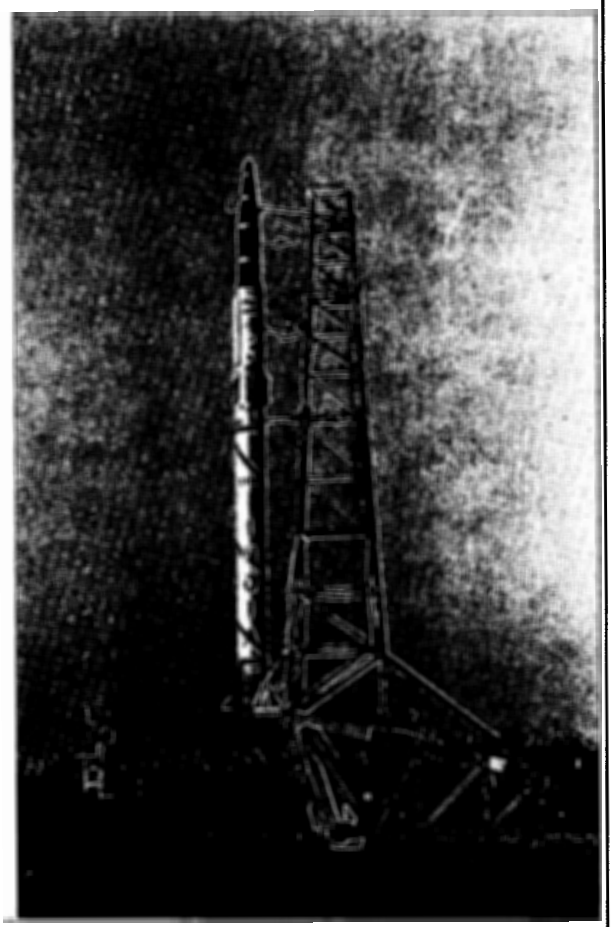


Prithvi (India)

Pakistan



Pakistan, with assistance from China, has been developing the Hatf 1 and 2. These missiles are short-range, road-mobile, solid-propellant, single-warhead ballistic missiles. The Hatf 1 has a length of 6.0 m, a diameter of 0.55 m, a launch weight believed to be around 1,500 kg, and a payload of 500 kg. It is assumed that the guidance is inertial, with four rectangular control fins at the base of the missile. The range is reported to be 80 km. *[Ref. 32]*



JANE'S INFORMATION GROUP

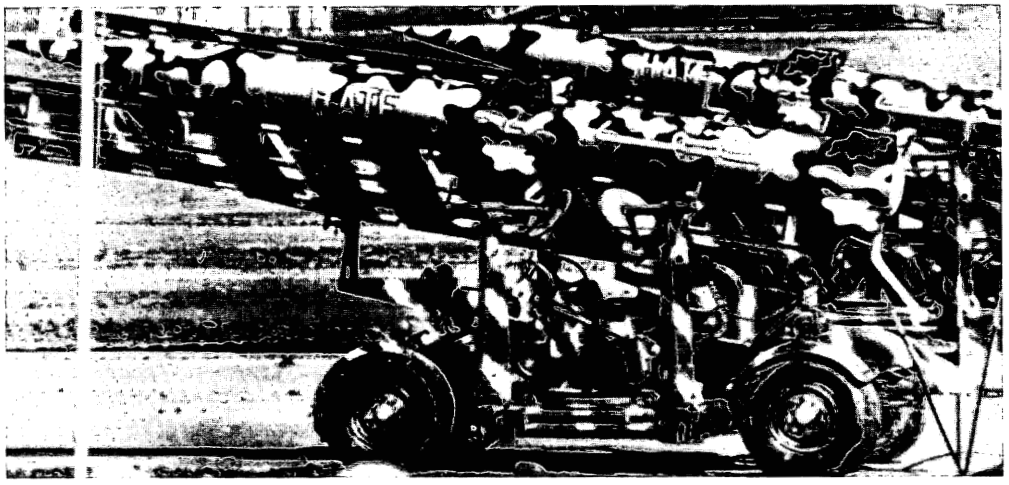
Agni (India)

The Hatf 2 has a range of 300 km, is 9.75 m long, has a body diameter of 0.82 m, and is believed to be a two-stage missile with four clipped delta fins at midbody and four more fins at the base. It is estimated that the Hatf 2 weighs about 5,500 kg, and it is reported to have a 500-kg payload. The first stage is 3.75 m long and the second stage is 6.0 m long. *[Refs. 32, 45]*

Hatf 1 and 2 are both ground-mobile missiles. The Hatf 2 missiles that have been publicly displayed are mounted on converted World War II antiaircraft gun trailers rather than modern TEL vehicles. It is believed that these missiles could be operational in 1992 with either conventional or nuclear payloads. In addition, Pakistan is thought to have acquired some Chinese M–11s with a similar 300-km range. It is not known whether these missiles are intended to replace Hatf 2 or just serve as a temporary "arsenal filler" until the Hatf 2 development is complete. *[Ref. 32]*

Libya

Libya had been supporting Orbita SA in Brazil in the development of the MB/EE family of road-mobile, solid-propellant ballistic missiles. A Brazilian missile was reportedly test fired in Libya in 1988. In addition, Libya has been advertising its indigenous Al Fatah or Iltesslot missile development program, which is rumored to have Brazilian, Chinese, and West German



JANE'S INFORMATION GROUP

Hatf (Pakistan)

technical support and participation. Its range was reported as 950 km. *[Refs. 29, 32, 37, 47]*

Egypt

Egypt attempted to develop long-range missiles in the 1960s but did not succeed. Egypt has been reported to have received assistance from North Korea in establishing a Scud B manufacturing capability. In addition, Egypt supported the Argentine Condor 2 development from 1984 to 1989 but withdrew when costs rose prohibitively. Egypt has initiated the Vector program, but it is not clear whether this is a new development or an outgrowth of the Scud or Condor programs. The Vector is reported to have a range of 1,200 km. *[Refs. 32, 44, 45, 48]*

Argentina

In the late 1970s, Argentina developed a space research rocket launcher, the Condor 1, which provided the infrastructure for a military ballistic missile program. Two developmental ballistic missiles have been identified with the Condor program. The Alacran is a single-stage, solid-propellant missile that is believed to be related to the Condor 1 space launch vehicle. The other missile is the Condor 2.

The Alacran is believed to be about 6.9 m long with a body diameter of 0.59 m. The missile has four moving delta control fins at the base for aerodynamic control within the atmosphere. It is estimated that the missile has a launch weight of about 1,750 kg and a single conventional warhead weighing about 500 kg. The range is about 200 km, and the missile is inertially guided. The Alacran program has been slow but steady, with the first test launch reported in 1989. *[Ref. 32]*

The Condor 2, which commenced development with help from Egypt, Iraq, and other nations, is a two-stage, solid-propellant missile that can deliver a 500-kg payload to a range of at least 900 km. It began development in 1982 to meet a recognized need for a longer range ballistic missile. The current status of the Condor program is unclear. Initially, Argentina received some technical support from countries in western Europe. The Egyptians provided funding in 1984, and the Iraqis followed suit a year or so later. In 1987, the MTCR slowed the transfer of technology and drove the cost up substantially. Egypt and Iraq withdrew their support in 1989, and the following year the Argentine government voted to cancel the program since it could not fund the Condor 2 alone. Despite the announcement that Condor had been discontinued as a military program, later statements were somewhat ambiguous, suggesting that Condor may still be under development as a covert program. This program appears to be called Badr 2000 in Iraq and Vector in Egypt. *[Refs. 29, 32, 43]*

Brazil

The Brazilian ballistic missile program is an outgrowth of Brazil's development of sounding rockets for near-equator studies of weather and other environmental phenomena. Technical assistance was provided from companies in Europe, Canada, and the United States.

Avibras SA, a Brazilian aerospace firm, is developing the liquid-propellant SS–300 ballistic missile with a reported range of 300 km. The SS–300 is reportedly a road-mobile Scud B derivative for which Avibras is receiving technical assistance, possibly including a guidance system, from the Chinese. Avibras has also been working since 1960 on the solid-propellant motors for the Sonda sounding rocket program. They are also developing a four-stage space launcher with this technology for China that could foretell a family of longer range, solid-propellant ballistic missiles. *[Ref. 37]*

The SS–300 is a road-mobile, single-warhead, short-range ballistic missile. It is believed to be 11.5 m long and 1.0 m in diameter. The launch weight is reported to be 6,400 kg with a payload of about 1,000 kg. Reports indicate that it is inertially guided. The missile is truck mounted. An unconfirmed report suggests that Iraq wished to purchase some SS–300 missiles in 1988. Avibras is also offering a 1,000-km version called the SS–1000. *[Ref. 32]*

Orbita SA, a consortium of five aerospace companies formed in 1986, has been responsible for development of the solid-propellant MB/EE series of short-range, road-mobile ballistic missiles. This program began in the 1980s and is reported

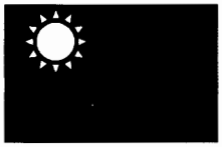
to utilize U.S. guidance components, also derived from earlier sounding rockets.

The MB/EE–150 is a short-range, road-mobile, solid-propellant, single-warhead missile. Three longer range versions (300 to 1,000 km), designated the MB/EE–300, MB/EE–600, and MB/EE–1000, are believed to be in development. There is also an unconfirmed report of a Brazilian test firing in Libya in 1988 during which a missile flew about 650 km. *[Refs. 32, 37]*

South Africa

South Africa, with Israeli assistance, has been conducting its own ballistic missile development program. It has been reported that South Africa has established two test facilities, one of which has been used to test its Arniston missile (which may be an Israeli Jericho 1). *[Refs. 32, 49]*

Taiwan



The Green Bee (Ching Feng) is a Taiwanese-built ballistic missile with an appearance and dimensions similar to the Lance. The Green Bee became operational in 1983. There has also been a report that Taiwan had been developing a 950-km-range surface-to-surface missile called the Sky Horse 1. *[Refs. 32, 44, 48, 49]*

South Korea

South Korea reportedly developed a two-stage, solid-fueled, surface-to-surface missile designated the NHK. This missile is believed to be a modified version of the U.S. Nike–Hercules surface-to-air missile provided to South Korea in the 1960s. There may be two versions of the NHK—one with a range of 180 km and another with a range of up to 250 km. A third missile, referred to as Hyonmu or NHK–A, is purported to have a somewhat longer range. *[Refs. 32, 45, 51]*

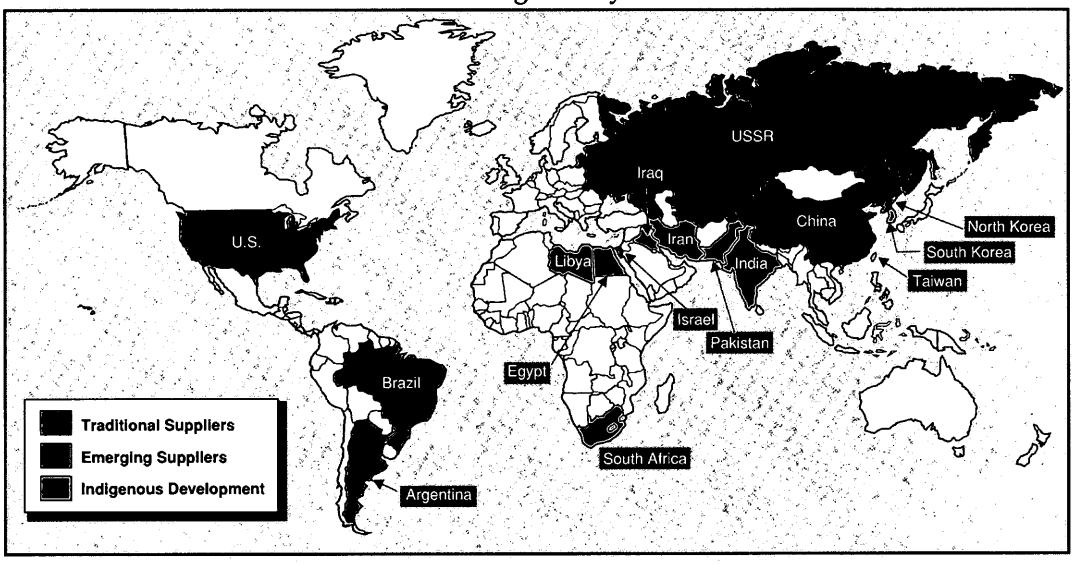
Chapter Three

Prospects for Proliferation

Of the 28 countries that possess operational or near-operational ballistic missiles with flight ranges greater than 30 km, 23 have the capability to produce them, 5 have been supplying missiles to others, and 18 have ongoing indigenous capability that could lead to a supplier role in the future. China, North Korea, and the USSR have been the major exporters of ballistic missiles, with the United States and possibly Israel as lesser players. Five of these present or future producers as yet deal only in unguided multiple rocket launcher (MRL) rockets—not surprising since nearly every aspiring producer enters the market with an MRL system.

Missile Suppliers and Developers

There are three traditional and four emerging suppliers in the world. Missiles are produced indigenously in nine additional countries.



CURRENT MISSILE SUPPLIERS

Together, the USSR, China, and North Korea have sold ballistic missiles to 10 non-Warsaw Pact countries. The USSR has sold and leased the production rights to the Scud and has sold the SS–21 to several countries in the Middle East. North Korea and China have sold related technology to Middle Eastern countries and, in the case of China, to Pakistan as well. The missiles produced by both North Korea and China can trace their lineage to technology given or sold to them previously by the Soviets.

The United States has sold a number of Lance ballistic missiles to NATO countries and other U.S. allies. In addition, the Israelis may have provided Jericho 1 missiles or the associated technology to South Africa.

Missile Recipients and Producers of Ballistic Missiles With Ranges Greater Than 30 km

Country	Produce	Buy	Country	Produce	Buy
Afghanistan		X	Saudi Arabia		X
Argentina	X		South Africa	X	
Brazil	X		South Korea	X	X
Chile	X*		Spain	X*	
China	X		Syria		X
Egypt	X	X	Taiwan	X	X
France	X		Turkey	X*	
India	X		United Kingdom	X	
Indonesia	X		USSR	X	
Iran	X	X	United States	X	
Iraq	X	X	Vietnam		X
Israel	X	X	Yemen		X
Libya	X	X	Yugoslavia	X*	
North Korea	X		**Total Producers/Buyers**	23	13
Pakistan	X	X	**Total Possessors**	28	

*Unguided MRLs only.

Current Ballistic Missile Suppliers

Missile	Range (km)	IOC	Customers
USSR			
SS–21	120	1975	Bulgaria, Czechoslovakia, East Germany, Hungary, Poland, Romania, Syria, Yemen
Scud B	300	1965	Afghanistan, Bulgaria, Czechoslovakia, East Germany, Egypt, Hungary, Iran, Iraq, Libya, North Korea, Poland, Romania, Syria, Vietnam, Yemen
China			
M–11	300	1991	Pakistan (?)
M–9	600	1991	Syria
CSS–2	3,000	1971	Saudi Arabia
North Korea			
Scud B	300		Iran
Scud C	600		Iran, Syria
United States			
Lance	130	1972	Belgium, Germany, Israel, Italy, Netherlands, South Korea, United Kingdom
Israel			
Jericho 1	500	1990	South Africa (unconfirmed)

POTENTIAL MISSILE SUPPLIERS

The emerging missile suppliers are those industrialized nations that have just begun selling—or trying to sell—missiles to other nations. Countries usually start selling cruise missiles before ballistic missiles since the former are easier to develop. Indeed, the majority of the missiles that have been sold are cruise missiles *(see Chapter Seven)*. However, Argentina and Brazil began negotiations for sales of ballistic missiles as well. None of the attempts are known to have been successful, although a test flight of a Brazilian missile was reported in Libya.

Potential Missile Suppliers

Missile	Range (km)	IOC	Customers
Argentina			
Alacran	200	1994	
Condor 2	900	TBD	Egypt, Iraq (not consummated)
Brazil			
MB/EE–150	150	1991	
MB/EE–300	300		
MB/EE–600	600		Libya (not consummated)
MB/EE–1000	1,000		
S–300	300	1991	Iraq (not consummated)
S–1000	1,000		

OTHER INDIGENOUS BALLISTIC MISSILE DEVELOPMENTS

A number of other countries have developed missiles indigenously for deployment within their own borders. To date, there have been no reported attempts to sell the resulting products. Egypt, India, Iran, Iraq, Libya, Pakistan, South Africa, South Korea, and Taiwan are believed to be developing ballistic missiles. Several other countries, like Chile, Indonesia, and Syria, appear to have the financial resources and technological infrastructure necessary to develop their own missiles. However, this section is concerned with actual—not potential—missile developments in developing countries.

SCUD PRODUCTION QUANTITIES

The Scud B has been the most widely produced and exported ballistic missile in the world. It has been included among the arsenals of former Warsaw Pact countries, Afghanistan, Egypt, Iran, Iraq, Libya, North Korea, Syria, Yemen, and possibly Algeria and Vietnam. No production quantities are known for certain; estimates range from 5,000 to over 10,000. Some data exist, however, on use and inventories of Soviet-manufactured Scuds in developing countries. Afghanistan is believed to have launched over 2,000 in its civil war against *mujaheddin* guerrillas. Egypt fired a handful against Israel in the 1973 Yom Kippur War, as did Libya in 1986 against a U.S. Coast Guard facility on the island of Lampedusa off Sicily. Iraq launched 361 Scuds against Iran during their 1980–88 war. It also launched about 100 Scud B and modified Scud missiles during the 1991 Persian Gulf war, and at least 65 were destroyed on the ground during the war or by U.N. inspectors following the cease-fire. Moreover, estimates of Scud inventories of Soviet origin include over 100 in Egypt, over 240 in Libya, 54 in Syria, and 18 in Yemen. It was originally estimated that there were up to 800 additional Scuds in Iraq prior to the war, resulting in a total Soviet export of at least 3,500 Scuds. It is not known whether any of the newly independent members of the Commonwealth of Independent States are continuing production of Scuds.

More recently, several countries have sought to produce Scud missiles indigenously. The leader in this effort, North Korea, successfully reverse-engineered the Scud B in the mid 1980s. In 1987, North Korea exported 90–100 Scuds to Iran, suggesting a monthly rate of 8–10 for this shipment alone. These missiles were then used during the 1988 "war of the cities" with Iraq. More recent estimates of a minimum of 50 Scud B missiles

Indigenous Ballistic Missile Efforts				
Country	**Missile**	**Range (km)**	**IOC**	**Status and Comments**
Egypt	Scud variant	300	TBD	North Korean support
	Vector	1,200	TBD	In abeyance
India	Prithvi	250	1992	In test phase
	Agni	2,500	1995	1st stage tested
Iran	Iran–130	130	1990s	In test phase
	Scud B, C	300	TBD	North Korean support
Iraq	Scud B	300	TBD	North Korean support
	Al Hussein	650	1988	Used in Gulf war
	Al Abbas	900	1990	
	Badr 2000	1,200	TBD	In abeyance
	Al Aabed	2,000	1995	In test phase
Libya	Al Fatah	300–950		In development
North Korea	No Dong 1	1,000	Mid 1990s	In development
Pakistan	Hatf 1	80	1992	In test phase
	Hatf 2	300	1992	In test phase
South Africa	Arniston	500	TBD	In test phase
South Korea	NHK–1, 2	180	1978	Conversion of Nike–Hercules
	NHK–A	260	TBD	In development
Taiwan	Green Bee	130	1983	On hold
	Sky Horse	950		On hold

produced annually by North Korea would yield a current inventory of a few hundred.

North Korea also appears to have developed an extended-range version of its Scud B. This system, often referred to as the Scud C, might have been operational since late 1989. It has been purchased by Syria (150) and Iran (170). South Korean reports suggest that at least 36 Scud Cs are deployed in a regiment just north of the DMZ. This report and data on later known shipments of such missiles (at least 24 in Syria and some in Iran) suggest an annual production rate of several dozen per year.

Other manufacturing efforts have been less successful. Iraq might have possessed an indigenous capability to produce Scud B copies before the Gulf war. Its prewar inventory of perhaps 900 Scuds includes a number of modified versions that appear to have been built from previously purchased Soviet Scud Bs. It is uncertain whether all of Iraq's Scud Bs were imported or if some were developed indigenously soon before the war. Following the war, Iraq's known short-term ability to produce Scud-type missiles was virtually eliminated, but reports persist that some production facilities might exist at hidden underground locations, and indigenous production could resume if the associated infrastructure is not destroyed in compliance with the U.N.-imposed cease-fire resolution. Egypt and Iran are pursuing the capability to manufacture Scud missiles, but it is not known whether any have been produced. *[Refs. 52, 53, 54, 55, 56, 57]*

INCREASING BALLISTIC MISSILE RANGE

Ballistic missile proliferation has resulted in a number of countries developing short-range ballistic missiles (SRBMs) with a range of 300 km or less, as typified by the ubiquitous Scud B. Such SRBMs threaten some U.S. allies, overseas facilities, and key transportation routes.

More ominous is the prospect of developing longer range ballistic missiles with a range of 1,000 km or more. These systems can threaten a broader array of U.S. interests. They can be based farther away from a country's borders, thereby diminishing the ability to execute a successful preemptive strike against ballistic missile launch sites. Moreover, due to their typically low accuracy, some longer range ballistic missiles may be more suitable for delivery of payloads that do not require a high degree of accuracy for their effectiveness—nuclear, biological, and chemical warheads. Thus, a country that is attempting to develop or acquire such missiles might also have some incentive to concurrently pursue weapons of mass destruction.

A country interested in obtaining a longer range capability has three options: converting space launch vehicles (SLVs) into ballistic missiles, modifying SRBMs to extend their range, or purchasing a complete system.

Space Launch Vehicle Conversion

SLV programs have been used in the past for development of ballistic missiles, although more often than not the situation has been reversed—that is, ballistic missile programs have been used to develop SLVs. In any case, the task is fairly straightforward since SLVs are very similar to ballistic missiles, differing only in types of payload and of guidance and control packages.

Covert conversion of SLVs to ballistic missiles has certain political and military advantages. For example, SLV development may be viewed by outside nations as more benign than outright ballistic missile development. An SLV program thus can be expected to attract greater foreign technical assistance as well as circumvent technology control efforts such as the MTCR, which limits the transfer of many SLV technologies for nonmilitary space applications. Circumvention of technology

Developing Country Space Launch Capabilities

Country	Sounding Rockets and Space Launch Vehicles	Longer Range Ballistic Missiles	Orbital Launches (1970–90)	Comments
China	Long March (CZ) −1, −2, −3, −4	CSS	28	Scientific and communications
India	Centaure, Rohini, SLV−3, ASLV	Agni	3	Achieved orbit capability in 1980
Israel	Shavit	Jericho 2B*	2	Offeq satellite launched September 1988; cooperation with South Africa
Argentina	Condor 2*	—	—	Claims to be shifting military emphasis on Condor 2 development to SLV
Brazil	Sonda II, III, IV; VLS	SS−1000*	—	Future developments uncertain
Indonesia	RX−250	—	—	Sounding rockets launched since 1976
Iraq	Tamouz 1	Al Aabed	—	Tamouz satellite launcher tested December 1989; future uncertain at best
Pakistan	Shahpar, SUPARCO	Hatf*	—	Cooperation with China

*Under development

Source: *Ref. 58*

controls for covert missile development is particularly attractive for states that seek to develop missiles with ranges greater than 300 km—the lower bound on missile range under the MTCR—but whose efforts have been stalled due to MTCR technology transfer restrictions. Covert missile development through an SLV program also could decrease the likelihood that neighboring countries would respond to the perceived threat with their own missile development efforts.

In practice, SLV conversion has been little used compared with other missile acquisition options, such as direct transfer of ballistic missile systems, accumulation of technologies for indigenous missile development, and use of foreign technical expertise. In most missile-capable states, a military orientation of the rocket/missile program has preceded an SLV effort. Outside of the United States and the former USSR, few countries today even have SLV programs. China, India, Israel, Brazil, Iraq, Pakistan, Argentina, and Indonesia have sounding rocket test ranges, and Taiwan is expected to develop one in 1992. Only China, India, and Israel, however, have launched payloads into space. (South Korea and Brazil are regarded as being close to achieving a space launch capability.)

Only Brazil and India can be considered to have followed the SLV conversion path to ballistic missile development. Brazil's space program was initiated in the mid 1970s, resulting in the launch of the Sonda IV sounding rocket in 1984. A few years later, ballistic missile development began in earnest, with several missiles currently in the R&D stage.

The link between space launch activities and ballistic missile development is clearer in the case of India. Its SLV and satellite development program is long running and ambitious, owing much of its success to more than 20 years of technical assistance from the West. India began to develop sounding rockets in 1967, and in 1980 it launched its first satellite on an SLV–3 rocket. A program to develop a short-range ballistic missile with Soviet assistance was canceled in the 1970s. It was not until 1988 that India indigenously developed and tested the short-range Prithvi missile. A year later, India successfully tested the two-stage, longer range Agni ballistic missile, the first stage of which is based on the SLV–3.

The preceding suggests that the states most likely to elect the SLV conversion option are those that (1) have considerably longer range targeting requirements against potential adversaries and (2) do not possess the air or naval power projection forces to fulfill those requirements. This could be the case for India, Brazil, Israel, and Indonesia. For example, Israel has developed two ballistic missiles: the 500-km Jericho 1 and the 1,500- to 2,500-km Jericho 2. The latter is believed to be similar to the Shavit satellite launch vehicle.

Of particular concern is the technical assistance that nations with an established SLV capability can provide to countries that are otherwise stymied in their efforts to acquire more capable ballistic missiles. Economic competition between the United States, Western Europe, and Japan could erode the traditional barriers to sales of their highly advanced SLV technology to developing countries. Such sales might also be seen as attractive to leaderships in the newly formed Commonwealth of Independent States. China is assisting with the development of the embryonic Pakistani space program; Pakistan launched its first experimental satellite in China in July 1990 aboard a Chinese Long March rocket. Given the commonality of SLV and ballistic missile technologies, joint ventures to promote commercial space development in developing countries might inadvertently lead to advances in ballistic missile capability, thereby decreasing security in some regions of potential conflict. *[Refs. 54, 58, 59, 60]*

SRBM Range Extension

The majority of proliferated missiles are either those with ranges under 300 km or cruise missiles. In addition to posing a tactical threat to nearby countries, these weapons provide the basic technology necessary to develop longer range missiles. For this reason, these shorter range missiles are included in this discussion. (Cruise missiles are discussed in Chapter Seven.)

Indigenous missile programs generally start with simple designs that are unguided, use solid propellants, and have ranges of 30 km or less (e.g., MRL systems). Short-range guided ballistic missiles with increased accuracy and range often follow. Continued progress is measured simply in terms of further increases in range and accuracy, possibly culminating in intercontinental ballistic missiles like those that dominate the strategic

arsenals of the United States and the former Soviet Union.

Four developing countries have modified short-range ballistic missiles to extend their range: China, North Korea, Iraq, and Israel. Of these, only China has extended the range of the missiles out to ICBM distances. China initially received help from the USSR in the late 1950s to produce the CSS–1, a missile with a range of 1,200 km. Thus, the extension in range was effectively "borrowed" from the Soviets. The longest range missile that China is known to possess is the 10,000-km CSS–4.

North Korea and Iraq have developed missile programs that are based on the Soviet Scud. The USSR supplied Scud technology to North Korea in the mid 1970s and also apparently licensed the rights to produce the missile at that time. This effort, with financial aid from other developing countries, resulted in the production of Scud Bs, which were available for both domestic use and for export. The North Koreans then proceeded to modify the 300-km Scud B in order to extend its range, resulting in the 600-km Scud C. This missile also has been exported to the Middle East (Iran and Syria). In addition, North Korea is reportedly developing the No Dong 1, a missile with a range of 1,000 km.

Iraq originally purchased Scud B missiles from the USSR. However, there was no known licensing agreement signed for the production of these missiles. Nevertheless, the Iraqis proceeded to produce Scud Bs, probably with outside assistance. They have since modified this vehicle to develop the Al Hussein and Al Abbas. Both have increased range over the original Scud B, probably a result of the combination of a payload weight reduction and an increased propellant load. Iraq is also believed to be developing the Al Aabed, a derivative of the Tamouz I space launcher. It is estimated to have a range of 2,000 km.

Developing countries can be grouped roughly according to the technology bases that would permit them to increase ballistic missile range. China, India, and Israel have indigenous ballistic missile programs for longer ranges, hold alleged or known stockpiles of weapons of mass destruction, have launched payloads into space using indigenously developed SLVs, and possess the most impressive military production infrastructures among the developing nations. Brazil, Indonesia, South Africa, South Korea, and Taiwan currently lack longer range ballistic missiles but possess SLV programs, have an adequate high-technology base, and have a robust defense production infrastructure that would enable them to develop such missiles if the political will and fiscal resources to do so are present.

Argentina, Egypt, Iraq, North Korea, and Pakistan possess substantial low-technology military production capability. However, they suffer from a variety of circumstantial constraints (such as lack of political will and fiscal resources, a virtually nonexistent high-technology base, international isolation, and internal instability) that impair their ability to indigenously develop longer range ballistic missiles for the foreseeable future.

Iran, Libya, Saudi Arabia, and Syria possess the weakest military production infrastructures among the ballistic missile proliferators, with little or no indigenous ballistic missile development, and no SLV or other high-technology development activities. However, most of these states possess the wealth needed to purchase from abroad what they lack—the indigenous capability to produce.

Note that, with the exception of a few countries, developing nations often lack at least one key component of technology or funding capability that would facilitate ballistic missile development. This suggests that, in the future, developing states with a common interest in ballistic missile acquisition might collaborate to develop such missiles, based on optimal exploitation of their various comparative advantages. An example would be collaboration between a country that lacks the sophisticated technology base required, but that possesses great wealth, and a country that typically possesses the advanced missile or SLV technology base required, but that lacks the necessary funding. This has occurred already in the aforementioned China–Saudi Arabia CSS–2 deal. More arrangements of this kind can be expected, given MTCR and other export control efforts, and, more importantly, the inherent difficulties that nearly all developing countries face in fielding advanced technology weapons. *[Refs. 51, 61, 62, 64]*

Missile Purchase

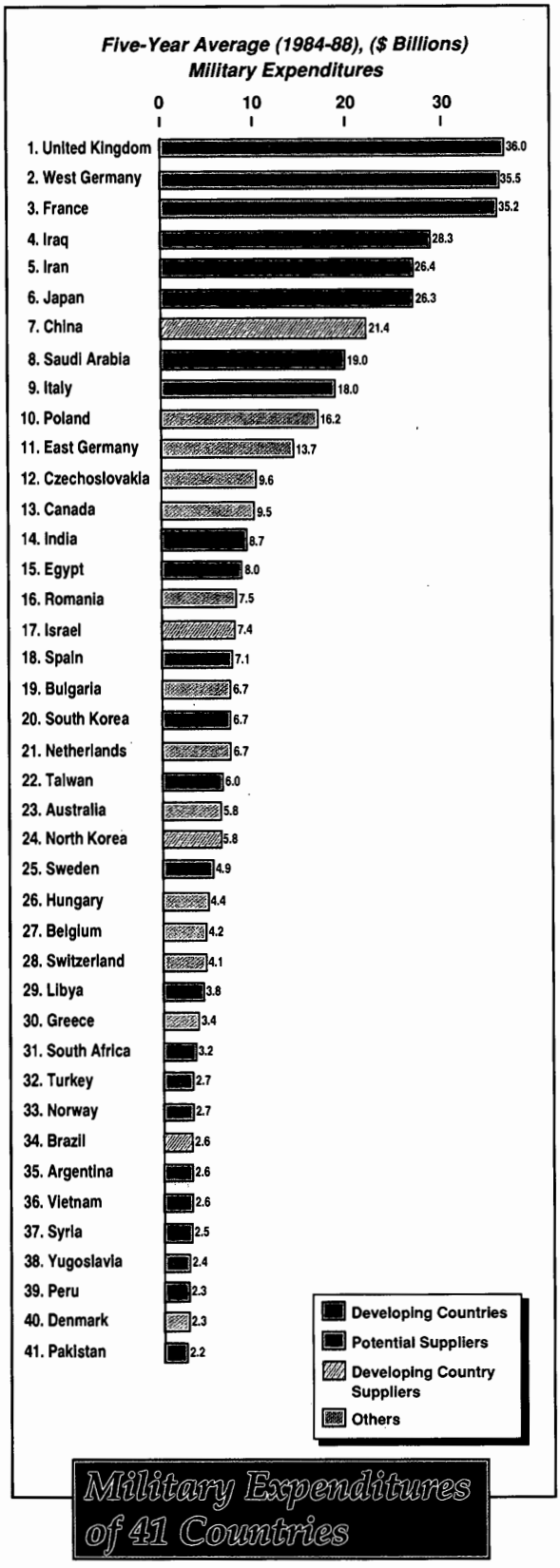
The third way that a country can obtain a longer range ballistic missile capability is by directly purchasing a system rather than developing its own from available short-range missile technology. The only example of this method has been the Saudi purchase of a few dozen CSS–2 missiles from China in 1987–88. China is the only known supplier of missiles of this range capability (3,000 km).

ECONOMICS OF MISSILE PROLIFERATION

The proliferation of missiles began as an adjunct to the cold war—NATO/ SEATO versus the Warsaw Pact. The burgeoning arms market reflected the political, military, and economic realities of the times. Exigencies, both real and imagined, determined to a large degree the policies of the superpowers regarding missile transfers to the developing countries: build them for yourself and for your allies; sell them if you can, or give them away if it is deemed expedient to maintain the balance of power; teach others how to use them and how to build them. Little forethought was given to considerations such as shifting allegiances or newly emerging powers.

Two major uses of developing economic power have evolved. Some nations have taken advantage of educational opportunities and boot-strapped their internal technology forward with their technically trained elite. Others have used their enormous oil reserves to finance the purchase of missiles or the associated technology (and the technologists) while still taking advantage of developed nation educational opportunities.

Military expenditures, exports, and imports are important indicators of missile activities. Without considering the United States and the Soviet Union, 41 countries have military expenditures that averaged over $2 billion per year over the period 1984–88. All of the current or soon-to-be missile producers are in the top 41, save two nations that manufacture only unguided ballistic missiles for multiple rocket launchers. All of the remaining countries on the list except Switzerland own missiles that were purchased from one

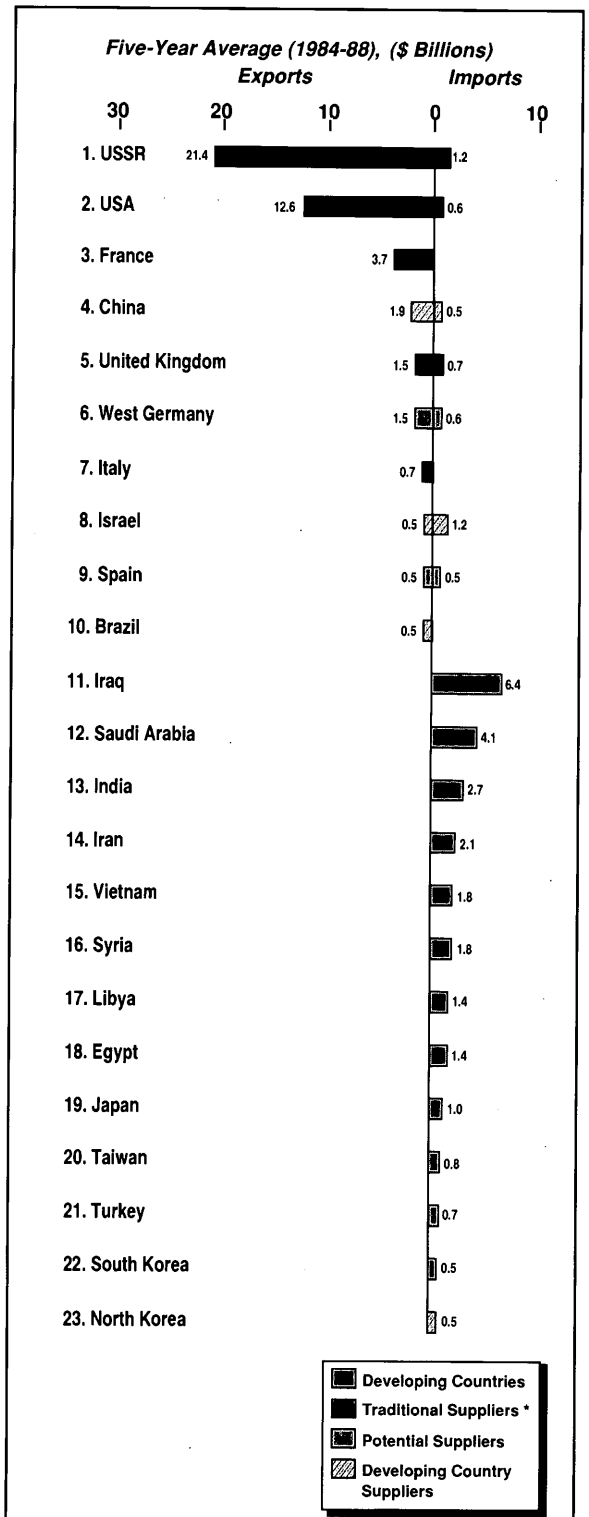


Military Expenditures of 41 Countries

or more of these producers. The successful missile producers have total military exports (all types of weapons, including aircraft, tanks, and small arms) greater than $500 million per year. The other missile producers either have not yet sold missiles or have sold them only in quantities too small to make any significant impact on total sales.

Most large arms importers are also developing producers. The exceptions are Saudi Arabia, which has historically purchased its weapons abroad; the Warsaw Pact countries, which were assigned parts of the former Soviet Union economic plan; Vietnam, which was subsidized by the former Soviet Union in earlier years; and Australia.

The key to missile development is the availability of money for military expenditures. In 1988, that threshold was about $2 billion. Eliminating the USSR, the Warsaw Pact countries, the United States, NATO and European countries, and Japan, the remaining countries of the top 41 include the major developing missile players, which are also the largest importers of arms and missile technology.



Imports and Exports of Missile Suppliers and Buyers

Chapter Four

The World Security Environment

The global strategic environment has drastically changed over the past several years. The principal manifestation of this striking change has been the peaceful revolution against totalitarianism in central and eastern Europe and in the Soviet Union, signifying the end of the cold war. This transformation represents a double-edged sword with respect to international security. Peaceful international change could be fostered, and international cooperation could be enhanced, in a global security environment where the superpowers no longer appear to be contributing to the outbreak of regional conflicts while maneuvering for geopolitical advantage.

At the same time, the superpower competition of the cold war served to restrain a number of political, territorial, ethnic, religious, and other potential conflicts. Disengagement of the United States and the Commonwealth of Independent States (CIS) from much of the world could result in the resurfacing of these conflicts in a number of regions, with an increased willingness by the parties involved to resolve their disputes by military means.

The principal features of the new security environment are as follows:

- Collapse of USSR and Warsaw Pact as military threats
- End of the East–West rivalry
- Rise of Japan and Germany as economic powers
- Resurgence of ethnic and religious tensions
- New awareness of resources and environment
- Rise of regional powers
- Increasing subnational conflict.

EUROPE AND THE COMMONWEALTH OF INDEPENDENT STATES

It is beyond the scope of this report to analyze the recent transformation of the Soviet Union as a superpower. Although disagreements continue between the member states of the CIS, it appears that a complete return to the politics of the past is unlikely. From the viewpoint of the West, the CIS can be expected to behave more responsibly on the international scene. The threat of Soviet-generated conflict in Europe has all but vanished, and the Warsaw Pact alliance ceases to exist. There was a certain predictability about the NATO–Warsaw Pact political–military rivalry that both focused and simplified Western threat assessment. The East–West rivalry also served to restrain long-running ethnic and religious tensions in Europe.

THE DEVELOPING COUNTRIES

Much of the rest of the world's security environment is punctuated with tensions between historical enemies armed with weapons of unprecedented destructiveness. This is a concern to the United States, especially in the context of the ballistic missile threat, for several reasons.

First, developing countries' arsenals were augmented considerably by the superpowers and their allies during the cold war. These arsenals are likely to continue to grow (although perhaps at more modest levels) in the new security environment, as the more developed nations export arms to lesser developed countries for economic reasons, and as the latter utilize their indigenous military production lines and scientific/technological expertise to develop improved weapon system capabilities. This trend in turn will increase the

lethality of proliferation threats, as seen in the Iran–Iraq war and the Persian Gulf war, where the intensity of combat rivaled that of any conflict since World War II.

Second, based on historical experience, U.S. interest in the military potential of developing countries is warranted. On those occasions since 1945 when U.S. forces were engaged in combat, the battleground was located in underdeveloped regions of the world, from Korea to Kuwait.

Third, history has shown that conflicts in developing countries are less likely to be resolved by diplomacy than conflicts between developed nations. Since 1945, more than 200 regional and local conflicts have been fought. As the superpowers disengage from those areas, there might be even less pressure than has previously been exerted on hostile countries to refrain from military resolution of conflicts.

Fourth, missile attacks played a prominent role in the last two major armed conflicts, the Iran–Iraq war and the Persian Gulf war. Leaderships harboring aggression toward their neighbors are likely to draw lessons from those wars as they consider use of missiles in future conflicts.

Finally, although the more developed nations have possessed impressive missile capabilities for some time, they also have had relatively stable command and control systems in place, up to and including the leaderships of those countries. This might not be the case in many developing countries, where some of the leaderships might best be characterized as "unstable."

Missile Use in Regional Conflict

Conflict	Date	Missiles Used/By	Against
Third Arab–Israeli War	1967	Styx*/Egypt	Israel
Third Indo–Pakistani War	1971	Styx*/India	Pakistan
Yom Kippur War	1973	Gabriel Mk 1*/Israel	Egypt
		Scud/Egypt	Israel
		FROG/Syria, Egypt	Israel
		AS–5 Kelt*/Egypt	Israel
Falklands	1982	Exocet*/Argentina	British fleet
		Sea Skua*/Great Britain	Argentina
Iran–Iraq	1980–88	Scud, FROG/Iraq	Iran
		Scud, Oghab, Iran–130/Iran	Iraq
		Styx*/Iraq	Iran
		Exocet*/Iraq	U.S.S. *Stark*, Iran
		Armat*/Iraq	Iran
		Silkworm*/Iraq	Iran
		Silkworm,* Harpoon (?)/Iran	Iraq
U.S.–Libya clash	1986	Scud/Libya	Lampedusa (Italy)
		Harpoon*/United States	Libya
Afghanistan	1988–91	Scud/Afghan army	Afghan *mujaheddin*
Persian Gulf	1991	Scud (Al Hussein), FROG/Iraq	Israel, Saudi Arabia, Qatar, Bahrain
		Tomahawk*/United States	Iraq

*Aerodynamic missile.

The recent Persian Gulf war provided recognition of some of the emerging realities of the new security environment and technology that has been proliferated. Long-range cruise missiles, antiballistic missile defenses, advanced reconnaissance systems, and stealth aircraft were all used together for the first time in major combat. Although advanced military technology was not the sole cause of the devastating defeat inflicted by the U.S.-led coalition on Saddam Hussein's forces, it clearly provided the coalition forces a decisive edge on the battlefield. That lesson is not lost on other aggressors who may be preparing for military confrontations and future combat. The war also provided further evidence of the willingness of adversaries in modern conflict to use missile attacks for political reasons or in desperation, even when facing a demonstrably superior adversary. Lastly, the performance of Patriot air defense systems was aided by the substantial time used to deploy and train batteries to fire them. Potential aggressors may have concluded that they cannot allow their adversaries so long a time to prepare air or missile defenses in a future conflict, thus raising the possibility of an increased role for preemptive missile strikes in their warfighting doctrines.

Against this background of the global security environment, a better understanding of the prospects of future aggression and the increased role of missile attacks in future conflicts can be gained. This, in turn, requires an understanding of the major areas of conflict around the world.

MAJOR CONFLICT AREAS IN THE WORLD

There are many areas of conflict, both existing and potential, in the world. From North Africa through the Middle East to the Persian Gulf, a number of unstable areas exist: western Sahara, Libya, and Chad; the Horn of Africa; the territories affected by the Arab–Israeli confrontation; the Kurdistan region crossing the borders of Turkey, Iraq, and Iran; and the Persian Gulf. These are areas of potential conflict where Western interests are involved.

In Asia, China continues to be preoccupied with its traditional zones of vulnerability—shared borders with former USSR states, India, and several nations of Southeast Asia—and the regions of the Pacific where its interests lie: the Korean peninsula and Taiwan. Afghanistan and the Indian subcontinent also remain zones of conflict.

The Korean peninsula is one of the most militarized and dangerous regions of the globe. The collapse of communism in Europe and in the USSR has left North Korea more isolated and unpredictable than ever. It remains to be seen whether North Korean militancy will survive the recent changes in the world and the anticipated passing of the hardline ruler, Kim Il-sung. Elsewhere, in sub-Saharan Africa and Latin America (Cuba, Central and South America), political trends are moving in a generally positive direction, especially as regards missile proliferation; however, those trends could reverse in the future in the face of a number of unresolved disputes.

Sources of Conflict in the Middle East and North Africa

The Arab–Israeli dispute (still unsettled after five major wars) and the unresolved Palestinian problem continue to be principal sources of conflict in the Middle East. This is demonstrated by the substantial weapon holdings of Egypt, Israel, Syria, Iraq, Iran, and Libya—the most heavily armed countries in the region. A number of chronic border disputes periodically flare up into major armed clashes, as was the case in the Iran–Iraq war and the Iraqi invasion of Kuwait. Nationalist movements like that of the Kurds continue to occur throughout the region. Other sources of tension in the Middle East include intra-Arab maneuvering for dominance, Iranian ambitions for regional influence, Islamic fundamentalism, and the rising expectations of increasingly well trained populations that are, in most places, excluded from the domestic political process.

Issues relating to natural resources could play an increasingly important role as a source of future conflict. The dependency of the world economy on the vast oil resources of the Persian Gulf makes this an area of continuing strategic importance, as do other considerations such as the position of the region astride traditional trading routes. The united Western response to Saddam Hussein's invasion of Kuwait was driven in part by these considerations. Concerns by some countries about the supply of fresh water could erupt

BARRY IVERSON/TIME MAGAZINE

Demonstrations Against U.S. Involvement in the Middle East

into a future conflict. The headwaters of the Tigris and Euphrates rivers are in Turkey, and diversion of or restrictions on the water supply could spark a conflict between traditional rivals Syria, Iraq, and Turkey.

Recent conflict in the Middle East includes the competition for control in Lebanon with the continued presence of Syrian forces, the Palestinian uprising against Israeli occupation of the West Bank, and instability in Iraq. Israel's expansion of settlements in the disputed West Bank has caused tension with Arab neighbors and with the United States, which withheld new aid in 1991 because of displeasure over the new settlements. Prolonged Iraqi weakness following its defeat in the Persian Gulf war might tempt incursions by Turkey, Iran, or Syria, each of which is well armed and wary of its neighbors' ambitions.

The 26 states in the Middle East possess standing armies, navies, and air forces that include more than 5.25 million troops under arms, 31,000 modern tanks and artillery pieces, 2,300 modern combat aircraft, and—in the case of Israel—one of the most impressive military production infrastructures outside the Organization for Economic Cooperation and Development. Since 1945, 76 armed conflicts have been fought in this area. It is in this context that Middle Eastern missile programs must be viewed. *[Ref. 28]*

Two acreas of conflict in North Africa also bear mention. The Horn of Africa is characterized by several territorial and ethnic disputes, especially in the Sudan and Ethiopia, both of which have coastlines on the strategically important Red Sea. Despite the overthrow of the highly repressive Mengistu regime in 1991, Ethiopia remains well armed and politically unstable. The territorial dispute in the western Sahara has been marked by periodic armed clashes since 1975 involving five countries—Morocco, Libya, Algeria, Mali, and Mauritania—and the POLISARIO guerrillas, with no end in sight.

Aside from any role in the western Sahara conflict, Mauritania presents a special problem in assessing the missile threat in developing countries. It was reported in early 1990 that Iraq was seeking access to a site in Mauritania to test long-range missiles such as the Tamouz 1 space launch vehicle.

Missile Programs in the Middle East and North Africa

Seven states in the Middle East have missile programs: Iraq, Iran, Syria, Egypt, Libya, Israel, and Saudi Arabia. (Yemen possesses only a few Scuds and SS–21s acquired from the USSR and has no indigenous missile program.) Israel is of particular interest because it also is believed to possess nuclear warheads. In October 1991, U.N. investigators found that Iraq was only 1 or 2 years away from developing an atomic weapon at the time of the 1991 Persian Gulf war. The Arab states and Iran have missile programs largely reflecting acquisition or modification of missiles provided by the USSR, China, or North Korea. The details of all these programs are discussed in Chapters Two and Seven.

The Middle East presents one of the more unstable proliferation problems, given the resources available (chiefly money from oil revenue) to

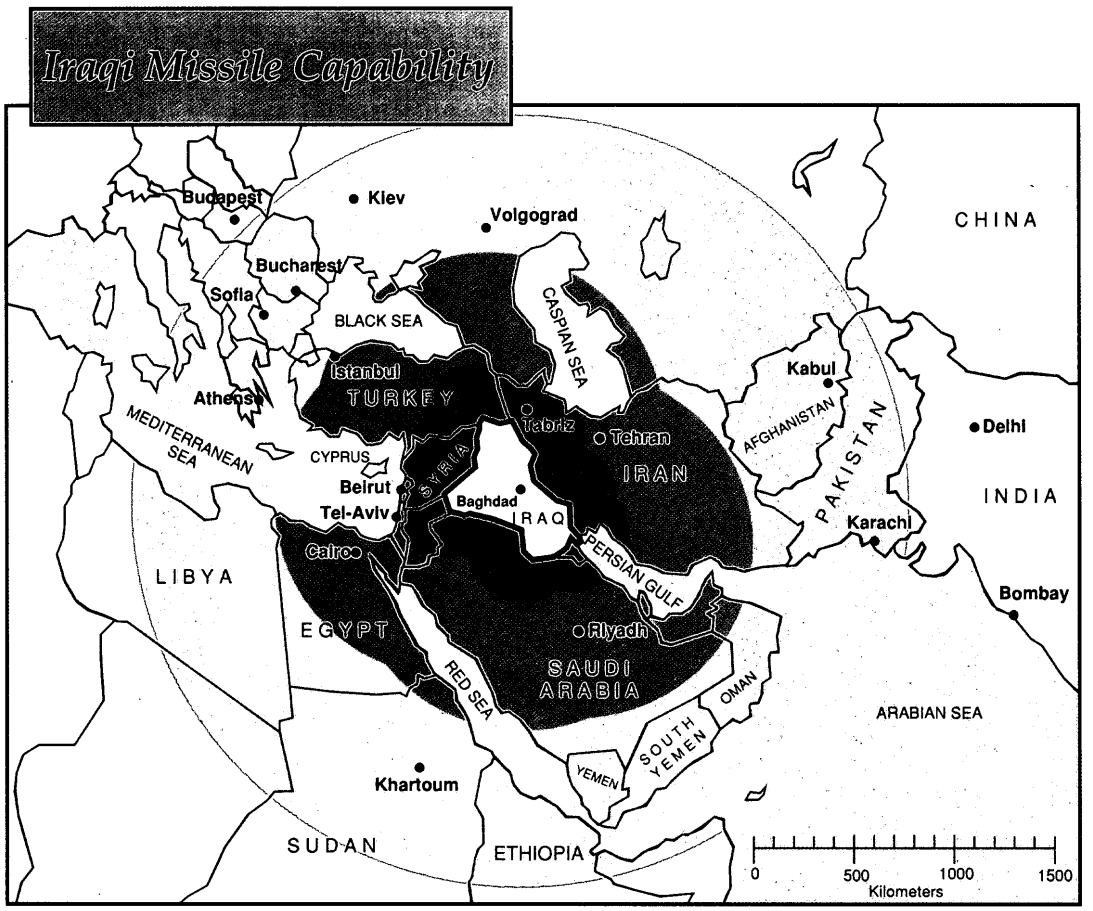
acquire new military systems, and reflecting the often intractable and bitter nature of the regional disputes. It was in the Middle East that modern ballistic missiles were first used in combat.

Iraq

Prior to the 1991 Persian Gulf war, Iraq had built a large military. The Iraqis used a variety of sources to obtain offensive missiles, including acquisitions from the Soviet Union and other nations, modifications by various consortia of technicians and engineers, and development of its own indigenous space launch industry.

With foreign assistance, Iraq modified Soviet Scud B missiles for longer range, producing the Al Hussein and Al Abbas. It was also in the process of developing a 2,000-km ballistic missile, the Al Aabed, similar to its Tamouz 1 satellite launch vehicle. Iraq was a partner with Argentina and Egypt in the abortive Condor 2 missile development effort and might retain some of the infrastructure related to that project. It is clear that a key element in Iraqi strategy was the possession of ballistic missiles. Iraq used FROG–7s and Scuds throughout the 8-year Iran–Iraq war. Longer range Al Husseins were launched late in the war against urban and military centers located in Tehran as a means of escalating the hostilities. *[Refs. 28, 32, 38, 39, 47, 65, 66]*

With FROGs and Scud Bs, the Iraqis found themselves only capable of supporting tactical troop movements and bombardment of local regions just beyond their borders. Other than Damascus, they were unable to reach their traditional Arab-world-dominance rivals— Cairo and Medina—or their other Moslem rivals— Tehran and Libya. Extension to 500+ km (Al Hussein) brought Tehran and Jerusalem within range; extension to 900 km (Al Abbas) added Cairo, Medina, and Instanbul to the target list. Extension to about 2,000 km (Al Aabed) would threaten Moscow.

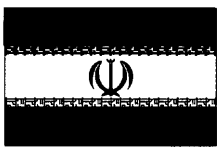


In addition to a formidable arsenal of offensive missiles, Iraq was vigorously pursuing nuclear, chemical, and biological weapons when the Persian Gulf war erupted. Iraq had used chemical weapons against Kurdish rebels and had armed some Scuds with crude chemical warheads, but these were not launched during the war. All of the 96 Scud-derivative Al Husseins and the five or more FROG–7s launched against targets in Israel, Saudi Arabia, and the Gulf states carried conventional warheads. The terms of the cease-fire agreement required that Iraq provide a full accounting of its nuclear, chemical, and biological weapons, its ballistic missiles, and its arms production facilities. The United Nations would verify that information, and the systems and facilities would be destroyed. *[Refs. 67, 68]*

The U.N. inspections, together with other information that has surfaced since the end of the war, have cast considerable doubt on the accuracy of the Iraqi declarations. Up to 800 Scuds could be hidden underground, and some nuclear materials might have been transferred to Algeria. It remains to be seen whether the political will exists in the international community to carry out the required destruction. Clearly, however, Iraq's war-making capability has been severely diminished by the allied assault, and attempts to rebuild its defense industry will be hampered as long as the international weapons embargo holds. *[Refs. 67, 69]*

Although Saddam Hussein remains in power, it is unclear how long he can continue to do so. A remilitarized Iraq with an uncertain leadership would be a continuing source of instability in the region.

Iran

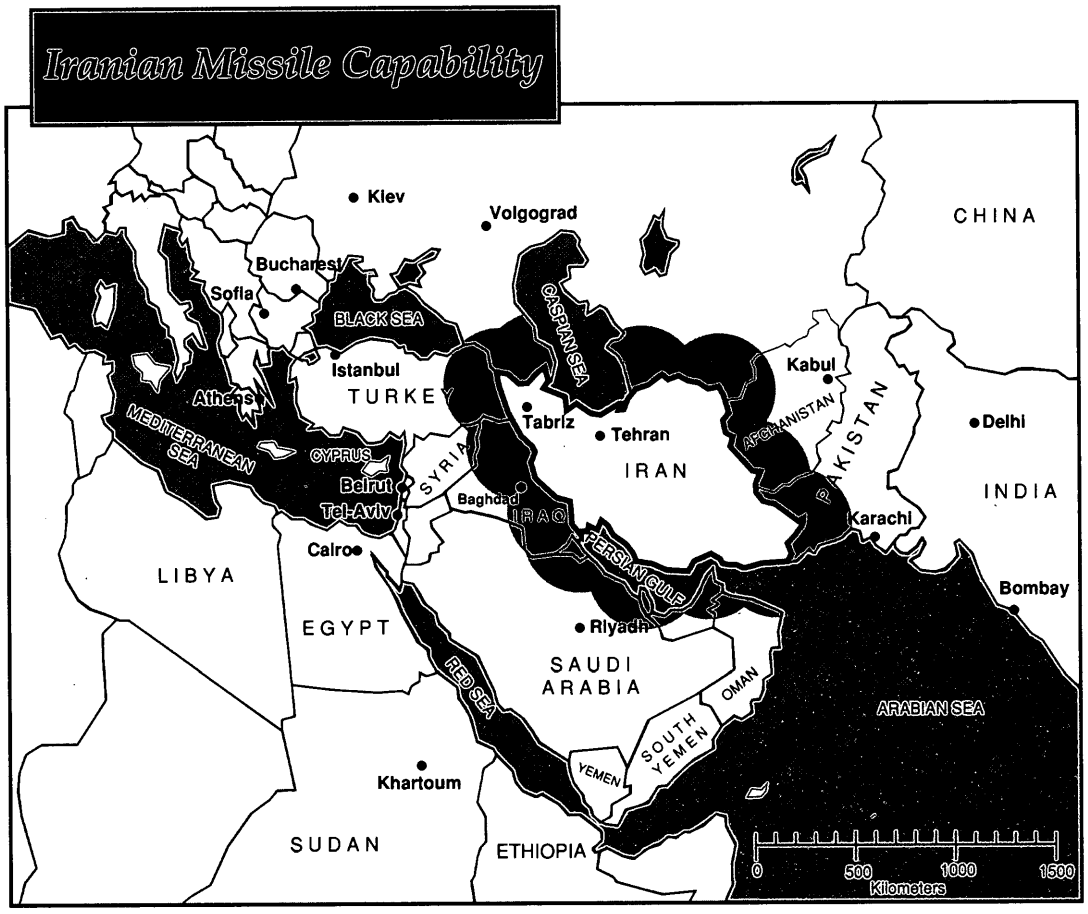


Iran's objectives include dominance of the Persian Gulf and security of Iran's borders against the mounting chaos in the region. Iran has played an important role in the attempts to destabilize Israel, is believed to be a principal sponsor of terrorist groups, and has led the resurgence of Muslim fundamentalism around the world. The Iran–Iraq war of the 1980s and isolation from traditional Western sources of supply have weakened the Iranian military. However, Iran has turned increasingly to China and North Korea for assistance in developing an offensive missile capability. Despite being a party to the Nuclear Non-Proliferation Treaty, Iran is suspected of having stocks of chemical and biological weapons and pursuing a nuclear weapons program. In October 1991, a member of the Iranian leadership was reported to have made the following statement in defense of the expansion of the Iranian nuclear program: "Because the enemy has nuclear facilities, the Muslim states too should be equipped with the same capability." *[Refs. 70, 71]*

In 1985 and 1986, Iran acquired a small number of Scuds from Libya and Syria, and in 1988 purchased an additional 100 Scuds from North Korea. With assistance from the Chinese, Iran also developed the capability to produce the short-range Iran–130 and the Shahin missiles. The Iranians may have established a facility for assembling Scud missiles from components acquired abroad. China reportedly is assisting Iran in building a factory to produce an 800-km range missile. *[Refs. 16, 40]*

During the Iran–Iraq war, all the Scuds fired at Iraq were conventionally armed. However, future use of chemical warheads by Iran cannot be ruled out. With the lack of spare parts and other supplies continuing to hinder the operability of its aircraft, Iran may employ missiles for longer range power projection in a future conflict. With Scuds, Iran could bombard Bagdad and Persian Gulf oil facilities but not much else, except in support of tactical troop movements. *[Refs. 16, 28, 32, 40, 65, 66]*

The Iranian military has undergone considerable turmoil and disruption since the overthrow of the shah in 1979, as has Iran's defense industry. The costs of the bloody war with Iraq drained Iran's resources but did not diminish its determination to develop a strong offensive missile force. The months following the Iraqi invasion of Kuwait in 1990 have seen an extensive rearmament program by Iran, including the acquisition of the extended-range Scud from North Korea. With weakened neighbors to the west and east, and with potential instability in the Soviet Muslim-dominated republics to its north, Iran might be tempted in the future to use its military power to "stabilize" its borders. *[Refs. 41, 42]*



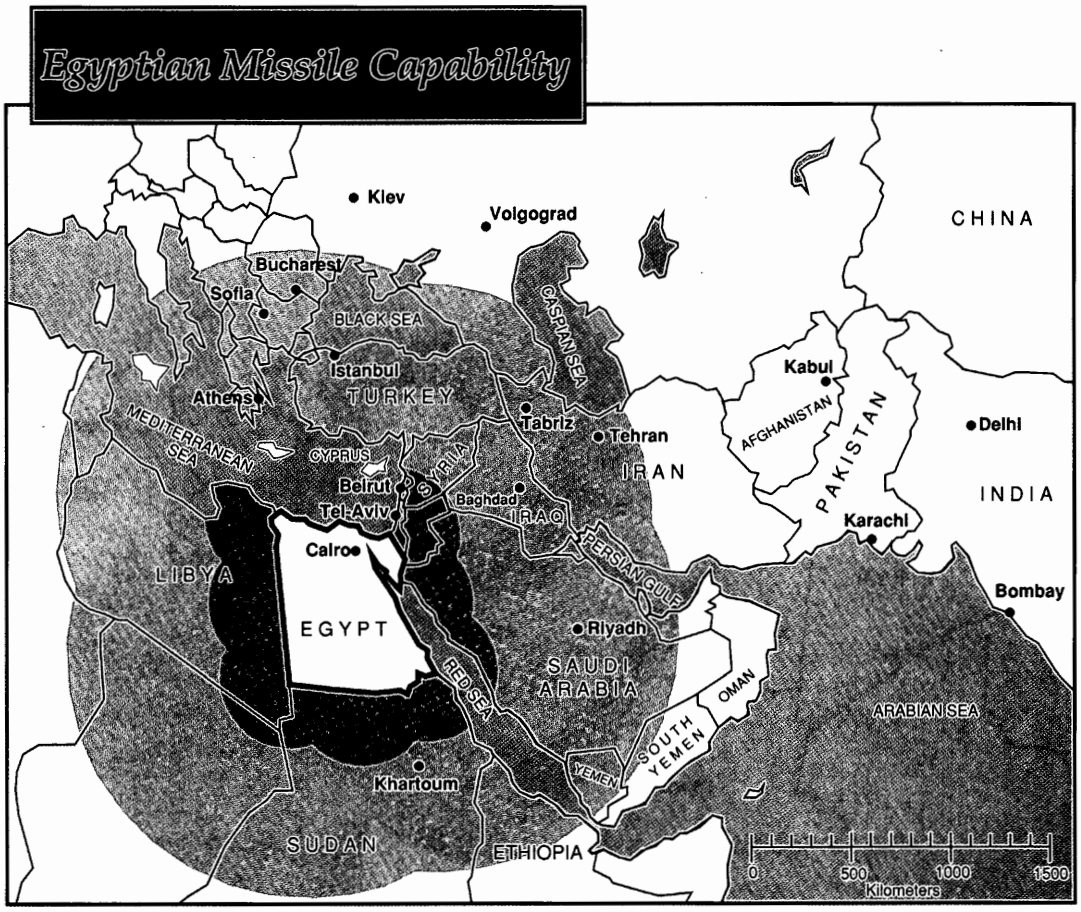
Egypt

Egypt's external security interests must take into account the continuing Israeli–Palestinian dispute, hostility from Libya, and the uncertain future of the regional military balances in the Middle East, as well as its own aspirations for leadership in the Arab world. Once a client of the USSR, Egypt now is a coalition partner of the United States, but retains an independent position with respect to its offensive missile programs. Egypt has an army capable of tactical and strategic mobility, and is one of the several developing countries whose military has actually used ballistic and cruise missiles in combat. Hosni Mubarak, Egypt's head of state, was trained as a bomber pilot in the USSR and commanded the Egyptian air forces during the 1973 Middle East war.

Egypt's guided ballistic missile arsenal consists entirely of Scuds. Egypt reportedly has nine Scud launchers deployed in two missile regiments of the Egyptian army. Egypt has collaborated, in the past, with Argentina and Iraq in an effort to produce a solid-propellant, inertial-guided missile, the Condor 2, with a range of 800 to 1,000 km, but withdrew from the project in the summer of 1989 due to domestic politics and frustration over Iraq's refusal to pay for arms acquired during the war with Iran. Egypt also has deployed the Sakr–80, an unguided rocket with a range of 80 km, and is developing a more advanced version of the Scud, perhaps with help from North Korea. *[Refs. 32, 39, 47, 73, 74]*

Egypt's Scuds give it capability to target most of Israel. The Vector, which is Egypt's version of the Condor 2, is being developed to provide range capability beyond 1,000 km. This allows Egypt to target Tripoli and its other Arab rivals in Damascus, Baghdad, Riyadh, and perhaps Tehran and Istanbul.

Latent political instability in Egypt is cause for concern. Should domestic problems worsen, an



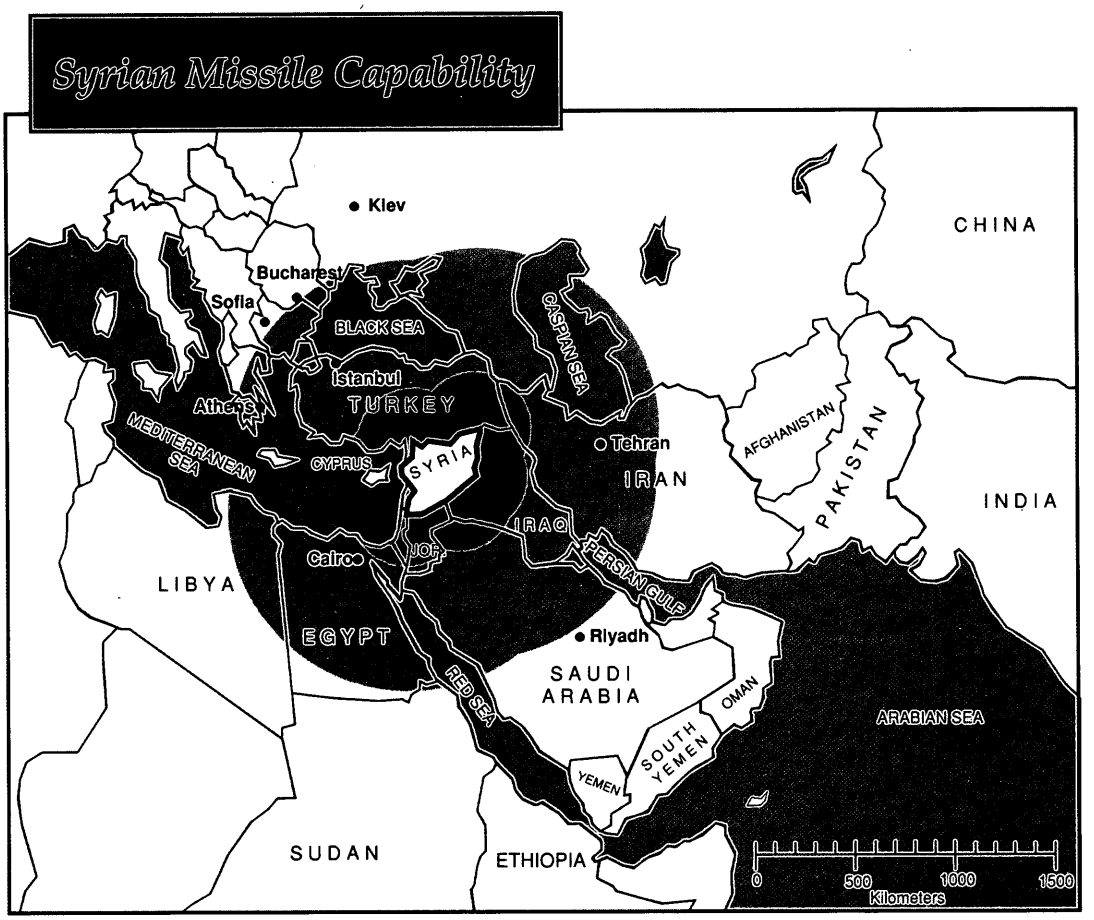
overthrow of the present leadership and its replacement by a regime whose interests are hostile to the United States would endanger U.S. interests in the region, given the size of Egypt's missile arsenal and its strategic importance in the region. *[Refs. 10, 32]*

Egypt is developing a fledgling aerospace industry based on local manufacturing, license assembly agreements, and indigenous weapon programs. This industry, coupled with government support for training a cadre of rocket scientists and engineers dating back to the 1950s and long-standing programs to acquire missile technology abroad, provides the foundation for future Egyptian missile programs. In 1988, the United States prosecuted an Egyptian for conspiracy to smuggle missile components out of the United States—an incident that proved embarrassing to the Egyptian government. Egypt reportedly has weapons stocks of chemical agents and has accomplished low-level research toward development of a nuclear capability. *[Refs. 39, 45]*

On a positive note, Egypt has been in the forefront of recent proposals to eliminate all weapons of mass destruction in the Middle East. *[Refs. 47, 70, 75]*

Syria

Syrian security policy combines elements of Hafez al-Assad's desire to consolidate and sustain control of Syria, the quest for influence in the Arab world, the confrontation with Israel, and posturing the Syrian military relative to shifting balances of power in the Middle East. This policy also is influenced by uncertainties of a continued supply of weapons from the former USSR. Humiliating defeats by Israel in the 1973 and 1982 wars convinced Assad of the need to acquire weapons to neutralize Israeli air superiority, strike at Israel's mobilization infrastructure, and balance Israel's nuclear capability. Syria's acquisition of advanced ballistic missiles is consistent with its doctrine of strategic parity—development of military and economic capabilities that



will enable Syria to prevail in a one-on-one war with Israel. *[Ref. 36]*

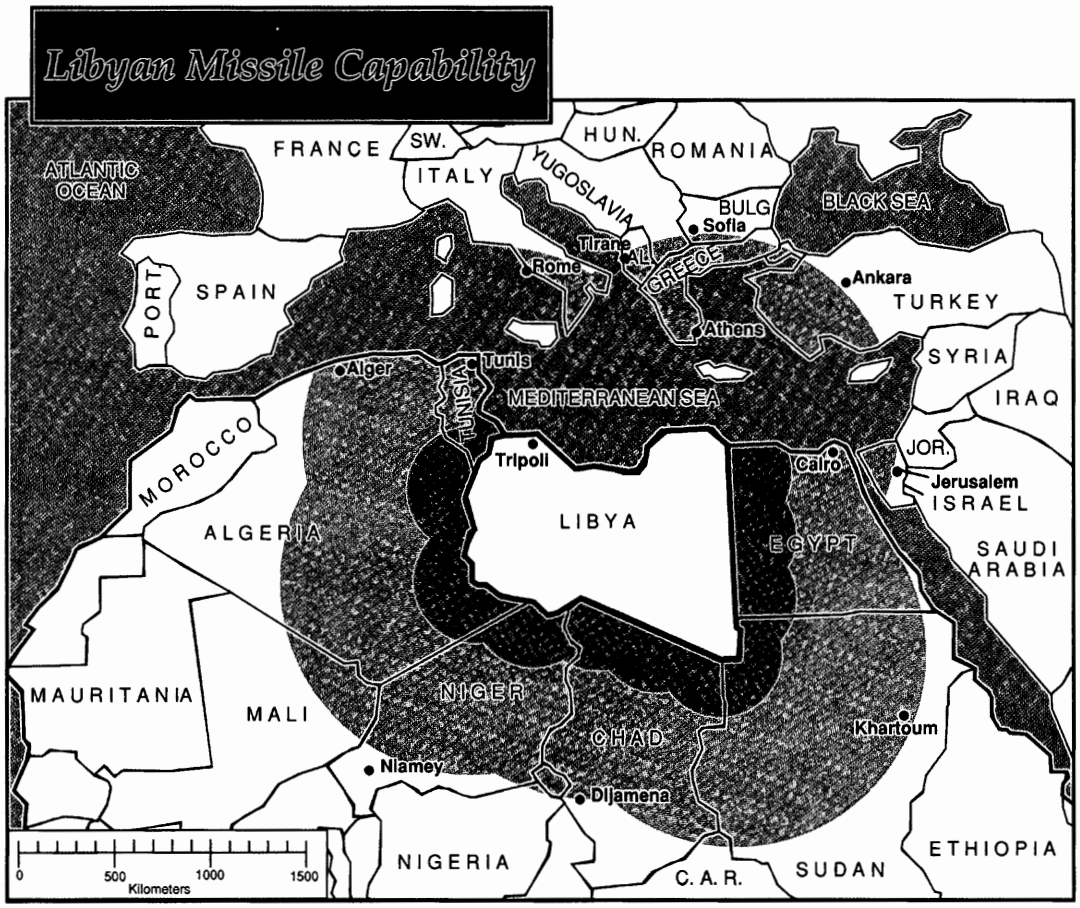
Syria received Scud B missiles from the Soviet Union in the early 1970s. Following the rout of their air force by Israel in the 1982 war over Lebanon, the Syrians sought to improve the capabilities of their missile forces to compensate for their inferior air power. They received SS–21 missiles from the Soviets in 1983, but subsequent attempts to purchase Soviet SS–23s (with a 500-km range) were unsuccessful. Syria also reportedly has a contract with China for the M–9 missile and is acquiring improved Scuds from North Korea. Syria has 18 Scud launchers and 18 SS–21 launchers. With its continued interest in upgrading Syria's missile striking power, the Syrian high command is building a formidable ballistic missile force. However, this buildup is constrained by economic problems that hinder Syria's ability to purchase advanced weapon systems. *[Refs. 28, 32, 36, 37, 39, 41, 42, 66, 78, 79]*

For the most part, Syria's Scud Bs give it only the capability for tactical troop movement support. M–9s or Scud Cs provide targeting to Istanbul, Bagdad, Tehran, and Cairo.

Syria has little or no defense industry and appears incapable of producing or modifying missiles. Beginning in 1987, the Soviets started reducing financial assistance to Syria, which caused Syria to widen its missile acquisition activities, including stronger ties with North Korea and China. Syria has received financial assistance from a joint Arab fund, from Libya, and from Saudi Arabia. *[Refs. 28, 45, 51, 66, 70]*

Libya

Since seizing power in 1969, Mu'ammar al'Qaddafi has aspired to a grand role in the Arab and African worlds. He has supported the struggle against Israel, assisted the POLISARIO guerrillas in the western Sahara conflict, fought Egypt in 1977, sent forces into Uganda in



support of Idi Amin in 1979, and intervened in Chad in 1980. Land disputes with Chad, Niger, Tunisia, and Algeria continue. Qaddafi is alleged to be a principal sponsor of numerous terrorist groups.

Libya acquired Scud missiles in the 1970s. More recently, Qaddafi attempted unsuccessfully to acquire M–9 and CSS–2 missiles from China and SS–12 and SS–23 missiles from the Soviet Union. Libya has also sought to acquire future missiles from Brazil, but it is uncertain if Brazil has accepted the offer or if Libya has the ability to pay. *[Refs. 28, 32, 37, 39, 45]*

Libya's Scuds provide only a tactical support capability. The 950-km Al Fatah would allow Libya to target all of Egypt, much of Algeria, and even Rome. The Chinese CSS–2 would allow them to target all of Italy and even Paris.

Libya is attempting to develop a defense industry for ballistic missiles and weapons of mass destruction. The Libyans appear to have weapon stocks of chemical agents and are conducting low-level research on biological and nuclear weapons. In the past, Libya has received assistance from western European firms on several of its programs. *[Ref. 39]*

Libyan missiles are viewed as an emerging threat to some nations on NATO's southern flank. Following the U.S. raid in 1986, Libya fired two Scuds at the U.S. Coast Guard facility at Lampedusa off the Italian coast, missing it narrowly; Crete is also within range of the Scuds. Libya could target cities in Sicily if it acquired missiles with ranges over 420 km. Employment of longer range missiles as terror weapons is a distinct possibility, given Qaddafi's support of terrorism and his reputed statement after the U.S. raid that he would have attacked New York with a nuclear-armed missile if he possessed one with sufficient range. *[Refs. 24, 39, 66, 70]*

Saudi Arabia

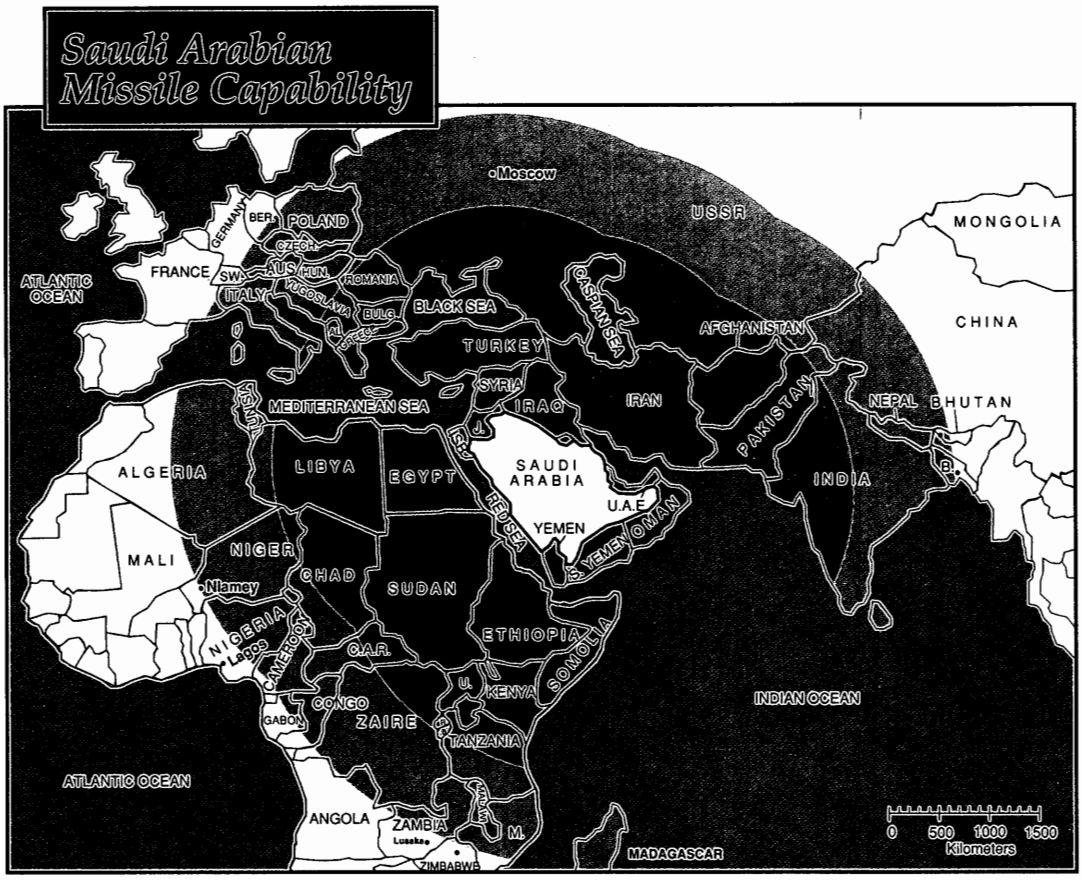
Saudi security policy is oriented toward maintaining a central role in the Arab

world, protecting its territorial and economic interests from regional threats (especially from Iran, Iraq, and Yemen), and participating in the Arab–Israeli struggle. Its highly centralized structure under the House of Saud has invested heavily in defense, acquiring weapons from a number of nations. The Saudi military buildup since the 1970s has emphasized external security concerns. By 1987, Saudi investment in defense had stabilized at about 23 percent of the nation's oil-rich GNP.

The Saudi ballistic missile force reportedly consists of up to 120 CSS–2 missiles acquired from China in 1988. The CSS–2 has a range of 2,700 km, although the missiles Saudi Arabia purchased may have a range more on the order of 2,400 km. The CSS–2 can strike the capitals of most countries in the Middle East and North Africa. However, it would need to be equipped with nuclear warheads to constitute an effective deterrent. It is not coincidental that these missiles were purchased following the onset of missile strikes against population centers during the Iran–Iraq war, which heightened Saudi concerns over Iranian missile capability. It also enhances Saudi influence in Arab circles, since the CSS–2 provides the Saudis with a range capability greater than that of any other Arab country. The CSS–2 is a relatively inaccurate missile, with a CEP on the order of 1,000 meters at a range of 3,000 km. The Saudis deploy the missiles at two launch sites south of Riyadh, one at Al Joffer and another at Al Sulaiyil, each equipped with four to six launch pads. The missiles reportedly are operated by Chinese technicians under Saudi supervision. *[Refs. 28, 32, 39, 45, 47, 66, 81, 82]*

Saudi Arabia's CSS–2s allow them to target nearly all of the Moslem nations from Algeria to Bangladesh plus Moscow and Rome. Even with a heavier first-generation nuclear warhead, the Saudi CSS–2s would still cover almost all of their Arab or Moslem competitors in the Middle East and northern Africa. Recent Saudi interest in shorter range missiles reflects their concerns with Yemen.

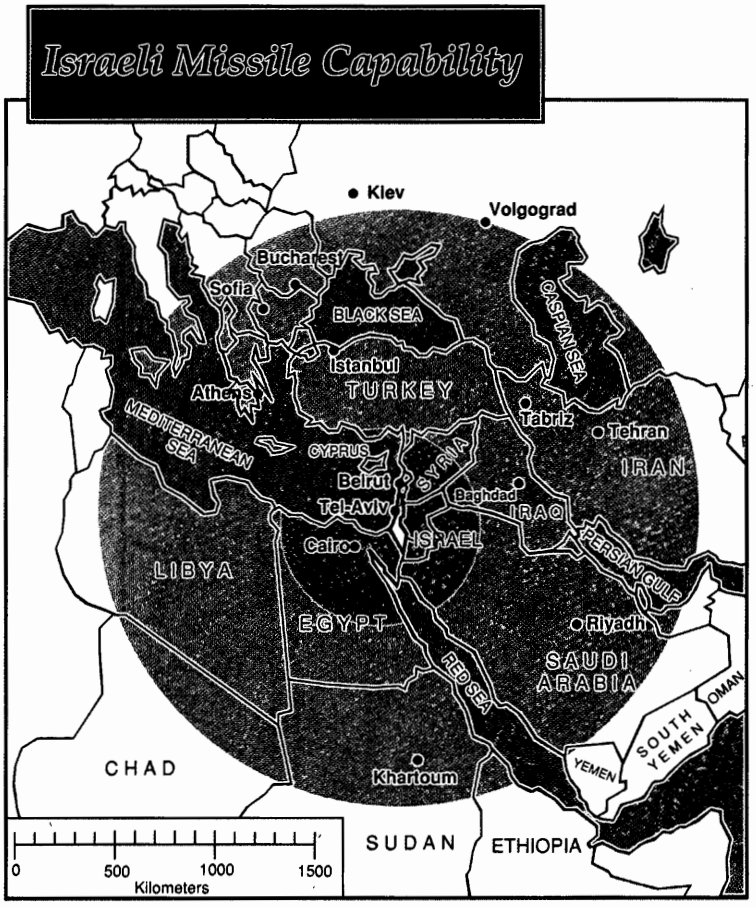
Prior to the Persian Gulf war, Saudi Arabia had embarked on building an indigenous rocket development program with some assistance from



Germany. Reportedly, the Saudis are focusing on small antiarmor missiles. The Saudis possess chemical weapon protective and decontamination equipment, but have no known CW stockpiles. Saudi Arabia is a party to the Nuclear Non-Proliferation Treaty and has declared that it will not attempt to arm its missiles with nuclear, chemical, or biological weapons. *[Refs. 39, 47, 83]*

Israel

Lacking strategic depth, Israel has, since its inception as a state, invested heavily in developing a superior military force that could exploit modern technology to prevail in conflict. Israeli military doctrine draws on Western models, modified and adapted to the circumstances of the region. Israel's security objectives include defending its territory (the ownership of which has never been recognized officially by most of its neighbors), deterring strikes on Israeli cities and populations, and coping with a continuing terrorist threat.



Israel's ballistic missile force includes Lance missiles acquired from the United States and Jericho 1 and 2 missiles developed indigenously with external assistance. With a range of 1,450 km, the Jericho 2 gives Israel a significant power projection capability. It can strike the territories of about 25 countries—all in the Middle East. With an active space launch program, Israel is capable of developing longer range missiles. *[Refs. 28, 32, 39, 47, 74]*

Israel's Jericho 1 gave it capability to target Cairo, Damascus, and Amman, but not much else of significance. Addition of the 1,500-km Jericho 2 extends its range capability to Tehran, Istanbul, Riyadh, and Tripoli.

The Israeli defense industry, one of the strongest in the developing countries, has experienced considerable turmoil since the early 1980s. However, relative to the defense industries of other developing countries, Israel continues to be a leader. Its broad-based programs include offensive ballistic missiles, space launch vehicles, and many of the aerospace subsystems needed to sustain a strong missile program. With U.S. assistance, Israel also is developing the Arrow antimissile missile and has acquired U.S. Patriot missile systems with limited ATBM capabilities. Israel is suspected of having stocks of chemical and nuclear weapons, and has conducted low-level research on biological weapons. *[Refs. 45, 49, 70, 84]*

Sources of Conflict in Asia

Since the beginning of the 1978 civil war and subsequent 1979 Soviet invasion, Afghanistan has been in a state of continual war. Of particular note, the Afghan army reportedly has fired over 2,000 Scuds against *mujaheddin* rebels during the ongoing conflict. This has had international implications, as Afghan army Scud missiles were reported to have fallen on Pakistani territory early in 1989.

The guerrilla victory predicted by many materialized in early 1992 with the collapse of the Najibullah government. An ongoing struggle for power, however, continues among the various factions.

The southern republics of the former USSR exacerbate the tension in the region. Iran, Turkey, and Pakistan have recently established an expanded Islamic common market consisting of Turkey, Iran, Afghanistan, Pakistan, Turkmenistan, Uzbekistan, Tadzhikistan, Kirghizia, Kazakhstan, and Azerbaijan. The Iranians are hoping to spread their form of Islam throughout the region and perhaps to enlist the services of Soviet-trained experts in missiles and warheads who live in these republics. Turkey and Pakistan are seeking economic advantage from countries whose populations share similar ethnic origins.

On the Indian subcontinent, India and Pakistan have had tense relations since gaining independence from Britain in 1947 and undergoing their subsequent partition. They have fought three times in the ensuing years and confronted one another over control of Kashmir. Despite a June 1989 meeting of military experts convened to establish confidence-building measures such as defensive-only deployments and a demilitarized zone in the region, violence has flared anew in the form of artillery exchanges. India tested a nuclear weapon in 1974, and Pakistan is rumored to be on the verge of acquiring a nuclear capability. A successful Pakistani test could induce a nuclear arms race in South Asia. Tension also exists over India's claims that Pakistan supports Sikh separatists in India's Punjab region. Religious strife, both inter- and intradenominational, continues to plague India and Pakistan.

In terms of international security, however, the presence of nuclear and missile programs in India and Pakistan raises the sobering prospect that the first nuclear war between two developing states may well be fought on this subcontinent. Although agreement was reached in 1991 to disallow preemptive attacks on each other's nuclear facilities, it remains to be seen whether a stable peace between India and Pakistan can be achieved.

Aside from the Soviet Union, China is the dominant military power in Asia. Its aging, hardline leadership is increasingly isolated since the collapse of communism in Europe and the USSR. Since 1979, China has sought to reform its economy by greater incorporation of market principles. Perhaps resistance to liberalizing its political system will wither as the gerontocratic leadership dies and is replaced by a new generation of leaders less encumbered by the totalitarian communist system. Such political reform would represent another step toward greater stability in China's strategic relations.

China has largely recovered from international consternation over the 1989 Tianenmen Square massacre of student pro-democracy activists. The Chinese gained world favor by voting with the U.N. majorities favoring a series of actions against Iraq in response to its invasion of Kuwait in August 1990. Although China abstained from the vote to authorize use of force, it was nevertheless a more cooperative world actor than many had expected.

China has not engaged in any direct military operations in recent years. It historically has had border and ideological disputes with the Soviet Union and Vietnam and border disputes with India. China claims sovereignty over the East China Sea and the Spratly and Paracel Islands in the South China Sea—claims that are disputed by its neighbors. The Chinese were a major combatant against U.N. forces in the Korean conflict. China also fought a major border war with India in 1962 and invaded Vietnam in 1979 over a political dispute.

Taiwan has been another source of instability in the region. Political and military tension between the competing Chinas has at times prompted U.S. involvement, such as the 1957 Taiwan Straits crisis. China continues to claim Taiwan as part of the mainland under Beijing's rule, but armed hostilities appear to be only a remote possibility.

As yet unclear are possibilities for conflict arising from domestic turmoil within and just outside China's borders. Some of the Soviet central Asian republics are populated by ethnic groups that are also found in China. An aggressive independence drive by these republics seeking to unite their separated populations could lead to clashes with China. Although China's belligerence and tendency to instigate conflicts seemingly have lessened, and advances of its missile programs have slowed considerably, it has been increasingly perceived by the United States as a troublemaker due to its willingness to export arms and missile technologies to developing countries. Recent exports of China's M–9 missile to Syria and its

M–11 missile to Pakistan could serve, over time, to exacerbate tensions in those regions. China may one day be of greater concern if control of its missile holdings is jeopardized by an internal crisis or civil war.

In the western Pacific region, the hardline North Korean leadership is becoming increasingly isolated. Its intentions in the area with respect to possible nuclear weapons development are difficult to ascertain. Although there have been some encouraging contacts between the two Koreas, it is unclear whether the political differences between these two states can be reconciled. They remain heavily armed, each with sizable forces deployed forward against the other. The United States continues to be concerned about North Korea's failure to observe its obligations under the Nuclear Non-Proliferation Treaty and considers this to be the most pressing issue in the region.

Vietnam, which remains heavily militarized, is still regarded as the principal threat to the ASEAN countries. It might well intervene again in Cambodia should an anti-Vietnamese leadership assume power there.

An exception to the relative tranquility that has characterized the states in the Pacific Basin is Indonesia. The country has been beset by armed conflict with separatist movements in East Timor and Irian Java and by Islamic extremist groups on Sumatra. Other insurgencies continue in Burma, Malaysia, and the Philippines.

The 23 states in Asia possess substantial standing armies, navies, and air forces that include nearly 23.5 million troops under arms, 63,000 modern tanks and artillery pieces, 5,160 modern strike aircraft, and—in the cases of China, India, North Korea, and Taiwan—impressive military production infrastructures. (Japan is not included in this list because of its unique military stance.) Since 1945, 58 armed conflicts have been fought in Asia. *[Ref. 28]*

Missile Programs in Asia

Seven Asian nations are known to have ballistic missiles: China, Afghanistan, India, Pakistan, Taiwan, North Korea, and South Korea. Two of these countries, China and North Korea, are exporting offensive missiles to other nations. The details of all these programs are discussed in Chapters Two and Seven.

China

With the world's largest population and third largest nuclear force, China is a major regional power in Asia and aspires to global influence. Its conventional forces are geared for territorial defense, not power projection, and the Chinese have placed a high priority on developing a nuclear arsenal. China's nuclear weapon program has been closely linked from the start to its ballistic missile program, which began with Soviet assistance. However, following the split between the two countries, the Chinese adapted the Soviet missile designs to their own purposes. This effort resulted in the Dong Feng (East Wind) series of intermediate- through intercontinental-range ballistic missiles: the CSS–1, CSS–2, CSS–3, and CSS–4. The CSS–4 can strike the continental United States. Among the developing countries, China has deployed the only SLBM, the CSS–N–3. Unconfirmed reports suggest that a new land-based missile, the CSS–X–5, is in development as a solid-propellant follow-on to the CSS–2. With many potential adversaries surrounding its extensive borders, China needs such longer range missile capabilities to project power over a broad range of contingencies. However, these systems might be viewed solely as a deterrent. China has never used ballistic missiles in its conflicts. *[Refs. 12, 33]*

The Chinese also began developing a family of shorter range ballistic missiles, probably in the early 1980s, with M–designators for missiles intended for sale abroad. The M–9 and M–11 missiles are part of this program. The Chinese reportedly are developing a new SLBM designated the CSS–NX–4, apparently designed to replace the CSS–N–3. *[Refs. 11, 28, 32, 81, 85]*

China has a highly developed nuclear and aerospace industry. The Chinese are working on a third generation of ballistic missiles. In the 1980s, they launched a robust export campaign for these weapons directed at other developing countries. China has stocks of nuclear and chemical weapons, and a research and development program for biological weapons. *[Refs. 70, 86]*

Afghanistan

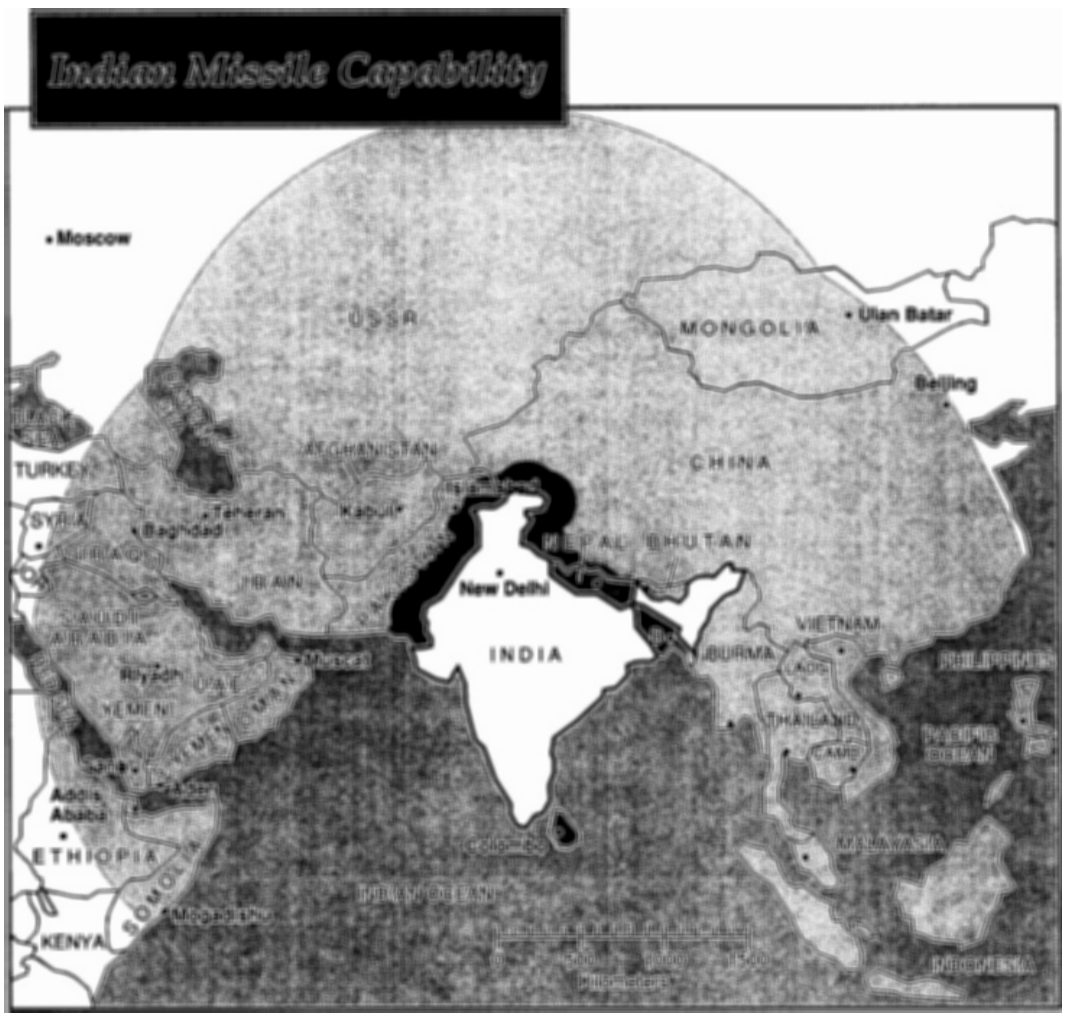
Afghanistan has recently emerged from a bloody civil war that started in 1979 when the Soviets invaded. With its history as an intensely proud and fierce warrior culture, the various warring factions have adapted modern technology to a long tradition of Afghan warfare.

During the war, Afghan government forces were equipped with perhaps 2,500 Scuds supplied by the Soviets at an estimated cost of $1.5 million per missile. These missiles were employed extensively in battlefield operations under the guidance of Soviet advisers. Over 2,000 Scuds (out of an estimated 2,500 missiles supplied by Moscow) were launched against the *mujaheddin* guerrillas, with only limited success. With the fall of the Najibullah government, the use of Scuds ended. *[Refs. 19, 22, 39]*

India

India competes with China as a major regional power in South Asia. The two nations fought a bitter border war in 1962. Three wars between India and Pakistan in less than 40 years, and continued Indo–Pakistani confrontations in Kashmir (marked by artillery exchanges), underscore the danger of a situation in which two powers with nuclear ambitions are pursuing offensive missile programs.

Next to China and Israel, India has the most advanced indigenous ballistic missile capability in the developing world. India developed the Agni and Prithvi ballistic missiles in close association with its space launch industry. The Prithvi has a range of 250 km and the Agni a range of 2,500 km. These missiles could be operational by the mid 1990s. Deployment of the Agni would allow India



to exert increased influence not only in South Asia, but also in portions of the Persian Gulf and the Pacific Basin, as well as the U.S. naval facility at Diego Garcia. *[Refs. 29, 32, 39, 46, 87, 88, 89, 90]*

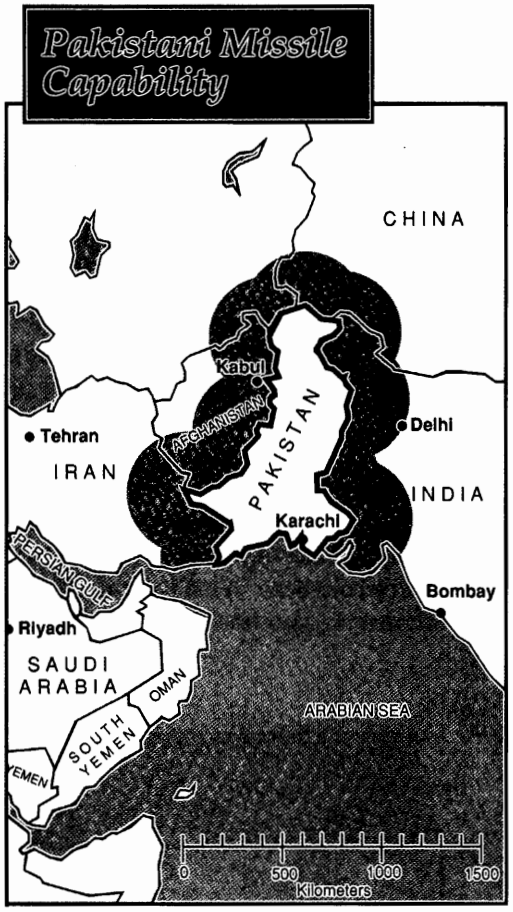
India's Prithvi ballistic missile has the capability to hit half of Pakistan, all of Bangledesh, and parts of the high-mountain territory of China and Burma. Addition of the Agni missile allows India to target most of China to Beijing, all of Southeast Asia, all of Pakistan, and all of Iran.

India's aerospace industry is well developed. Its entire military–industrial complex is one of the oldest, largest, and most diversified among the developing countries. India imports advanced aircraft from France and the Soviet Union and has its own light combat aircraft under development. India's successful space launch program serves as a surrounding infrastructure for the Integrated Guided Missile Development (IGMD) program, established in 1983. India detonated a nuclear device in 1974, and might have stocks of nuclear warheads (or at least the capability to produce them rapidly). India also has a low-level research program on chemical and biological weapons. *[Refs. 39, 70, 84, 88, 91, 92]*

India would be likely to employ missiles in battlefield operations, as it did with shorter range missiles in its 1971 war with Pakistan. Strategic missions are highly uncertain, particularly since India has published no formal doctrine for use of strategic systems and nuclear weapons. This raises the ominous prospect that a future missile war involving the use of nuclear weapons could be initiated through a misperception by Pakistan or China of India's intentions. *[Ref. 93]*

Pakistan

Pakistan defines its security interests relative to its neighbors, Afghanistan and India. India is the principal adversary, and the dispute over Kashmir could again erupt into war. Pakistan lacks strategic depth, and its territorial centers are located near the Indian border. Pakistan receives military assistance from China. U.S. assistance, precipitated by the Afghan war, is in abeyance because of U.S. concerns over Pakistan's efforts to develop nuclear weapons.



Pakistan, with Chinese assistance, is developing a family of missiles: the 80-km Hatf 1 and the 300-km Hatf 2, both of which may be operational by 1992; and the 600-km Hatf 3, which remains in the early stages of development. Pakistan also has contracted with China to import the Chinese-built M–11, a 300-km missile. *[Refs. 28, 32, 34, 39, 85, 86, 95]*

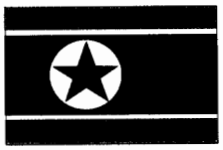
The Hatf 2 missile only gives Pakistan the capability to target the near portion of India where the Moslem population is large. Pakistan would like to acquire longer range missiles to allow it to target most of India.

Pakistan has limited indigenous missile development capabilities and space launch industries. It depends heavily on foreign assistance, especially from China, for its missile programs. Pakistan has an active nuclear research program and may be near to acquiring nuclear weapons. Pakistan also has an active research program for chemical weapons, and a somewhat less active program for biological weapons. *[Refs. 45, 70]*

In spite of these developments in missiles and advanced weaponry, Pakistan's long-range missile program appears to have stalled. Due in large part to international technology controls, Pakistan does not appear to be able to acquire the technologies required for full development and deployment of the Hatf 3 and space launch vehicles. Even with its Hatf 1 and 2 missiles, it is doubtful that either can carry an early-generation nuclear weapon or even large quantities of high-explosive munitions. *[Ref. 39]*

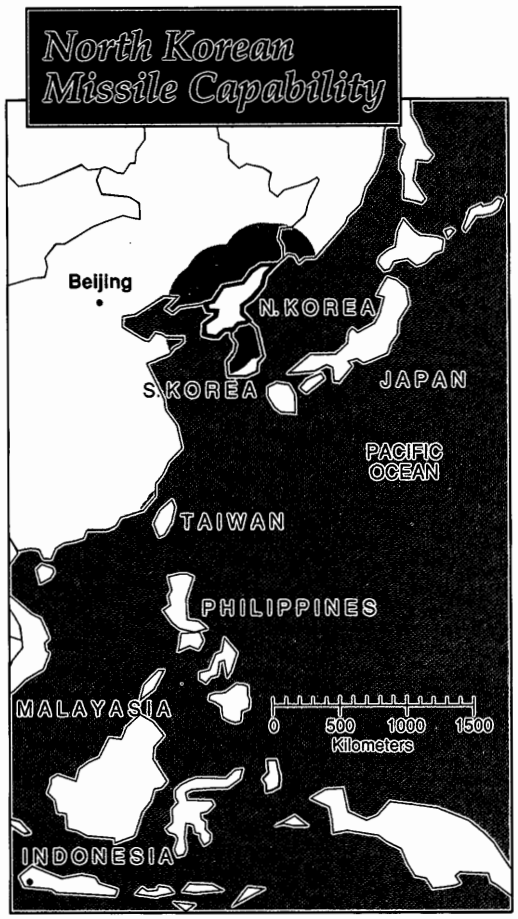
Nevertheless, Pakistan will remain a future threat to use and develop advanced missile systems. Its long-running competition with India and an unstable leadership (in which the military plays an important interventionist role) raise concerns about future missile exchanges in the region. As with India, the lack of any published Pakistani doctrine for strategic use of missiles and nuclear weapons could lead to an accidental war resulting from miscalculation. *[Ref. 39]*

North Korea



From the late 1940s, when Korea was divided along the 38th parallel, North and South Korea have confronted one another as mortal rivals. Technically, the two countries are still at war. North Korea is a highly militarized society, devoting 25 percent of its GNP to the military. Under a longstanding policy of military *chu'che* (self-reliance), North Korea has developed an extensive military production capability and is a major arms exporter to the developing countries. *[Ref. 39]*

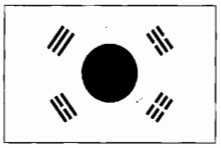
North Korea's ballistic missile arsenal consists of Scud missiles, including advanced derivatives of the Scud design. In 1976, North Korea launched a program, with help from Egypt and China, to develop an indigenous capacity to produce Scuds. In 1985, Iran agreed to finance this program, and by 1987 North Korea was producing Scuds at the rate of 8 to 10 missiles per month. In 1987–88, North Korea reportedly sold 90–100 Scuds to Iran. Currently, North Korea produces and deploys an advanced version of the Scud with a range of 500–600 km. Some of these reportedly have been purchased by Syria and Iran. In addition, there are reports that North Korea has developed an even longer range version, the No Dong 1, with a range on the order of 1,000 km. *[Refs. 28, 29, 31, 32, 39, 41, 53, 79, 96, 97, 98]*



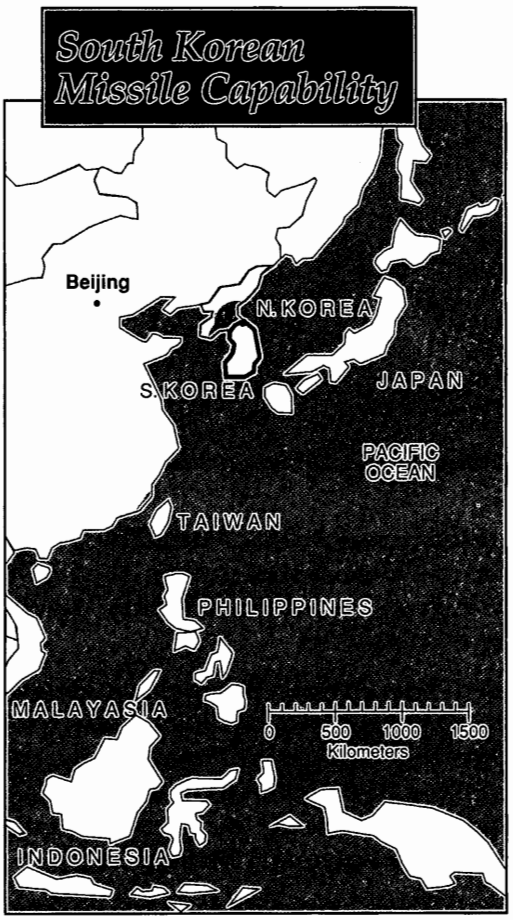
North Korean Scud Bs provide it with a capability to target most of South Korea. North Korea's pursuit of the No Dong is driven both by its interest in selling the missile in the Middle East and northern Africa and by its desire for targeting areas as far as Japan and Beijing.

North Korea has developed a substantial aerospace industry. In addition to ballistic and cruise missiles, the North Koreans build several types of military aircraft and components for MiG–21 fighters. North Korea engages in extensive efforts to obtain foreign technology for its missile programs. It likely has stocks of chemical agents, may have stocks of biological agents, and is pursuing an active nuclear program that is causing increasing concern in the region and beyond. *[Refs. 45, 70, 100]*

South Korea



After the devastation of the Korean conflict, with U.S. economic assistance and the protective umbrella of U.S. security commitments, South Korea transformed over several decades into a thriving industrial community on the Pacific Rim. The primary security orientation of South Korea continues to face north, with peaceful reunification of the Korean peninsula as its primary goal.



Largely because of U.S. policy encouraging South Korea not to build long-range missiles, South Korea's offensive missile arsenal has remained limited. The Korean SSM, a ballistic missile with versions ranging from 180 to 250 km, is a modification of the U.S. Nike–Hercules surface-to-air missile. It is believed to remain under development. South Korea plans to launch satellites into orbit by the second half of this decade; this achievement would have implications for long-range missile development. *[Refs. 28, 32, 39, 45, 51]*

South Korea will have the capability to target all of North Korea when the NHK–A becomes operational. The present capability only covers half of North Korea.

Taiwan

Taiwan, traditionally dependent on the United States for its security, embarked on a drive toward more self-sufficiency in the aftermath of U.S. normalization of relations with China in the late 1970s. It defines its security interests primarily in terms of resisting domination by mainland China. It has an impressive, diversified economy, and its defense industry is growing.

Taiwan's only known ballistic missile is the Green Bee (Ching Feng), reportedly developed with Israeli assistance and apparently based on the design of the U.S. Lance system. A 130-km missile about which little is known, the Green Bee was reported to have been canceled by the early 1980s, but rumors have surfaced that its development continues. A 950-km missile called the Sky Horse has been reported as under development, but little is known about it. Such a missile could strike much of southeastern Asia and China, and might serve as a deterrent if it existed. *[Refs. 32, 39, 49, 101]*

Taiwan appears to be focusing its efforts on development of aircraft, rather than missiles, for long-range power projection. In addition, Taiwan may have stocks of chemical agents and has pursued low-level research on biological and nuclear weapons. *[Refs. 32, 70]*

Sources of Conflict in Sub-Saharan Africa

Since 1945, most of the states in sub-Saharan Africa have emerged from colonial domination (often through wars of independence) to become newly independent nations. These states have been marked by political instability as they attempt to implement democratic systems in countries whose boundaries were set by colonial powers, often across tribal boundaries. However, conflicts in sub-Saharan Africa typically have been civil wars and coups instead of state-versus-state conflicts. This has been true for the two countries

in the region that have suffered the most casualties since 1945—Biafra (Nigeria) and Angola. Even though the latter possesses more troops and modern battle tanks, artillery pieces, and strike aircraft than any other nation in sub-Saharan Africa, it is difficult to envision Angola threatening to use force against its neighbors due to its economic difficulties, the waning of its Marxist fervor, and the lack of any border or ethnic disputes. Given the relatively undeveloped force structures and military infrastructures among the nations of sub-Saharan Africa, offensive missiles probably will not play a significant role in any conflicts in the region for the foreseeable future.

A possible exception is South Africa, which—with its system of apartheid—has been a major source of instability in Southern Africa for the past two decades. Much of the continent (and the world community) pressed for domestic reform; South Africa resisted and then responded by attempting to destabilize its neighbors. With the gradual passing of apartheid, however, South Africa has become less isolated from the world. Thus, the prospects for a more stable security environment are improving, as demonstrated by South Africa's recent decision to abandon its nuclear weapons program.

Sub-Saharan Africa is much less militarized than Asia and the Middle East. The 37 states in sub-Saharan Africa possess standing armies, navies, and air forces that include more than 880,000 troops under arms, 3,200 modern tanks and artillery pieces, 550 modern strike aircraft, and—in the case of South Africa—a military production infrastructure. Since 1945, 49 conflicts have been fought in sub-Saharan Africa. *[Ref. 28]*

Missile Programs in Sub-Saharan Africa

The only significant offensive missile program in sub-Saharan Africa is that of South Africa. This program has evolved with extensive assistance from Israel. The South African missile program is discussed more fully in Chapters Two and Seven.

South Africa

South Africa's security policy has been oriented toward threats on its borders and its isolation in the world community during the period of apartheid. South Africa recently fought wars with Namibia and Angola, culminating in 1988 with the signing of the Angola–Namibia Agreement, which called for Namibian independence, South African and Cuban withdrawal from Angola, and Angolan commitments to end sanctuary for African National Congress (ANC) guerrillas. In early 1990, South Africa legalized the ANC, and the movement toward greater liberalization and democracy at home continues.

South Africa has cooperated with Israel in missile (and perhaps nuclear) development programs. There have been reports that South Africa is developing a ballistic missile with Israel's help. South Africa announced in July 1989 that it had successfully tested a space launch booster, although some reports indicate that the missile was actually an Israeli Jericho 1. It is generally believed that any South African program to fully develop a missile would require substantial foreign technical assistance. *[Refs. 16, 28, 45, 49]*

South Africa has a sizable defense industry, centered around the state-owned South African Armaments Corporation (ARMSCOR). South Africa may have nuclear and chemical weapons, and has conducted research on biological weapons. However, in October 1991, the government announced that it was abandoning the "strategic emphasis" of its nuclear program. This announcement has been interpreted as indicating that South Africa is discontinuing its nuclear weapons and intermediate-range missile programs. *[Refs. 70, 102]*

Sources of Conflict in Latin America

Latin America includes the Caribbean, Central America, and South America. Much of Latin America emerged from a series of wars of independence with Spain and Portugal, fought largely in the 19th century. During the latter half of the 20th century, the region has been characterized by civil wars, border skirmishes, island and maritime sovereignty and resource disputes, insurgencies (assisted by the USSR during the cold war), periodic coups d'état, and drug-related violence. Brazil has traditionally sought a dominant position in the region, but Argentina periodically has contested that position (as evidenced by their rival missile and nuclear programs).

Recently, as the cold war has faded and democracies have become more common in Latin America, many of the immediate sources of conflict have receded. However, the region remains economically unstable, with several territorial disputes, and these recent trends toward stability could be reversed. An example of a lingering territorial dispute that led to armed conflict is the situation in the Falkland Islands (Malvinas) that led to the 1982 war between Argentina and Great Britain.

Although its fervor for exporting revolution might have waned, Cuba remains a particular source of potential conflict. It is heavily armed, with more modern battle tanks, artillery pieces, and strike aircraft than any other country in Latin America. Its communist regime stands in stark contrast to the capitalist and democracy-laden landscape of the region. An uprising against that troubled regime cannot be ruled out.

Drug-related violence has increased in recent years, especially in countries in the northern half of South America. It is conceivable that some drug-producing and -distributing organizations might use their extensive profits to acquire missile systems for use as tools of blackmail or in defense against attempts by militaries to attack the drug supply line at its source.

The 26 states in Latin America possess standing armies, navies, and air forces that include more than 3,900,000 troops under arms, 4,500 modern tanks and artillery pieces, 380 modern strike aircraft, and—in the cases of Argentina and Brazil—military production infrastructures. Since 1945, 33 armed conflicts have been fought in this area. *[Ref. 28]*

Missile Programs in Latin America

Argentina and Brazil have missile programs. A Cuban program, which has been effectively abandoned by the Soviets, is withering. The current governments of Argentina and Brazil, both possessing nuclear programs, appear to be cooperating with the West in efforts to stem the proliferation of offensive missiles, but a change of policy in those countries cannot be ruled out. An encouraging sign in the area of nuclear nonproliferation is that Argentina and Brazil have agreed to accept International Atomic Energy Agency (IAEA) safeguards on all their nuclear facilities and to take steps toward bringing into force the 1967 Treaty of Tlatelolco, which creates a Latin American nuclear weapons-free zone.

Argentina

Argentina's external security agenda traditionally includes confrontation with Britain over the Falkland Islands, competition for preeminence with Brazil, and border disputes with Chile along the Andes and in the waters south of Tierra del Fuego. The Argentine military used Exocet missiles with some effectiveness in the 1982 war with Britain, despite limited training at the time. Tensions with Great Britain have eased considerably, and relations with Brazil have improved.

Although Argentina appears to have no ballistic missiles deployed at present, it has vigorously pursued two missile development programs in conjunction with its space launch programs. In the late 1970s, Argentina began work on a space research rocket, the Condor 1, which was displayed at the Paris Air Show in 1985. The Condor 1 appears to have provided the basis for subsequent military ballistic missile programs. The Alacran, also under development prior to 1991, is believed to be a single-stage, solid-propellant missile with a range on the order of 200 km. With Egyptian and Iraqi assistance, the Argentines also have had under development the two-stage Condor 2, which is estimated to have a range of 900 km.

In April 1990, responding to significant U.S. pressure and to the withdrawal of much of the required foreign technology and assistance, Argentina announced it was canceling the Condor program. Whether it has in fact stopped remains unclear, as Argentina claims the Condor 2 remains a satellite launcher used for peaceful purposes. The Alacran program continues, as does Argentina's space program. Argentina previously entered into an agreement with Egypt and Iraq to pursue a ballistic missile program, which was subsequently abandoned due to political and fiscal constraints. Argentina has also pursued research on nuclear, chemical, and biological weapons. *[Refs. 32, 39, 43, 45, 54, 70, 103]*

Brazil

Brazil's concept of national security has political, psychosocial, economic, and military dimensions. Security and foreign policy are shaped by intense nationalism, a desire for regional preeminence, and concerns over the Argentine nuclear program. However, for the Brazilian military, domestic tranquility is the first priority in maintaining national security.

Brazil emerged in the 1980s as the leading arms producer and exporter among the developing nations, and the sixth largest arms exporter in the world. Brazilian arms have been attractive to developing countries because of their relative simplicity, high quality, and freedom from ideological connections. *[Refs. 102, 104]*

Brazil has been heavily involved in collaborative aerospace programs and in the development and production of missiles for export. Avibras, a privately owned firm with a reputation for professionalism, has been one of Brazil's leading exporters. Avibras was initially involved in space design and research, and then branched into tactical rocket and missile development programs for export to the rest of the world.

Avibras has developed the SS–300, a short-range, road-mobile, liquid-propellant, single-warhead ballistic missile under development since the early 1980s. The SS–300 is reportedly a modification of the Soviet Scud, which it resembles. It has also been reported that the Brazilian Aerospace Technology Center is modifying the Scud to produce a longer range (1,000-km) version, designated the SS–1000. In any event, it is unclear how much Brazilian design has actually been involved. Initial flight tests of the SS–300 were reportedly performed in 1987, and the missile could enter service this year. *[Refs. 37, 45]*

Avibras and other firms in Brazil's missile industry have suffered from declining domestic support, spending cuts, and difficulties in receiving payments for arms exports. It is still possible that Avibras could develop longer range ballistic missile systems, given the history of the company. Avibras has worked on the Sonda series of solid-propellant sounding rockets since the 1960s and is presently developing the VLS, a four-stage, solid-propellant satellite launcher with the ability to place a 160-kg payload in a 605-km circular orbit. Avibras has also formed a joint venture satellite-launching company with the Chinese. *[Ref. 49]*

Orbita, a consortium of five aerospace companies formed in 1986, is developing the MB/EE family of missiles: the MB/EE–150 (150-km range), the MB/E–300 (300 km), the MB/EE–600 (600 km), and the MB/EE–1000 (1,000 km). The MB/EE–150 has been marketed by Engemissil, a subsidiary of Brazil's state-owned Empresa Brasileira de Aeronautica (Embraer). It is believed to be able to deliver a 500-kg payload to a range of 150 km.

The MB/EE-150 has reportedly been offered to Libya for about $2 billion in financing over 5 years, although this could entail development of a family of missiles rather than just one version. There is a report that a Brazilian missile was test fired in Libya in 1988 over a range of 650 km. *[Refs. 16, 39, 45, 47, 84]*

Brazil was apparently developing nuclear weapons until the government announced in September 1990 that the program would cease. Brazil refuses to sign the Nuclear Non-Proliferation Treaty.

Cuba

Cuba's aging communist regime is under intense stress with the collapse of communism in the Soviet Union. Already largely removed from the political and economic activities of the global community, and with a faltering economy, Castro or his successors face the prospect of even greater isolation in the future.

Cuba has historically relied on outside support, primarily from the Soviet Union, to sustain its military, but whatever Soviet assistance remains can be expected to diminish quickly. However, Cuba may have access to other arms markets, such as China or North Korea. In March 1991, North Korea was alleged to have signed a contract with Cuba to export missiles and other antiair weapons. It also was reported that a North Korean military delegation, led by Chief of Staff Choe Kwang, had signed a military cooperation agreement with Cuba and visited a genetic-bioengineering institute, accompanied by the chief of the Cuban air force, to facilitate exchange of chemical warfare technology. *[Refs. 28, 39, 105]*

Chapter Five

Ballistic Missile Technology

Many of the ballistic missiles produced by countries throughout the world can be traced to German World War II designs. German rocket scientists captured by Soviet and U.S. forces were recruited for emerging rocket programs. The Scud in the Soviet Union and the Corporal and Sergeant in the United States became the first indigenous guided ballistic missiles. As time passed, the designs changed to accommodate mobile launchers and quick reload, expanding ranges, increasingly accurate guidance, more lethal warheads, and penetration aids (penaids) to ensure survival.

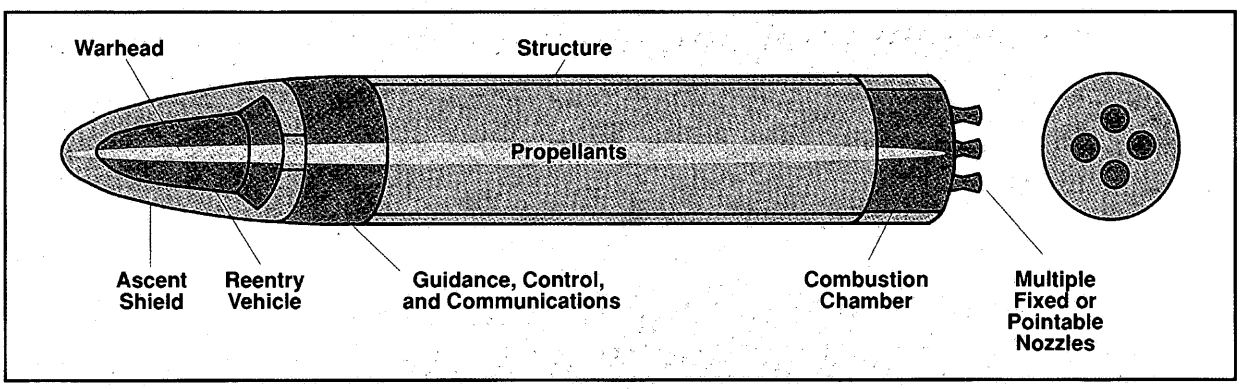
U.S. and Soviet missile programs progressed similarly in improving performance. As new countries enter into missile production, they typically start at the same point and then gradually add capabilities as experience, assets, and funding permit. Sometimes a step can be skipped with outside help, but overall progress is determined by available technology, expertise, and resources.

PERFORMANCE THROUGH TECHNOLOGY

The rationale for technology is to improve performance, and range is a critical measure of performance. For the Keplerian (gravity-controlled) portion of a ballistic trajectory, there is an envelope of possibilities about the basic minimum-energy trajectories. Minimum-energy trajectories are trajectories that maximize the range achievable with a given thrust performance. Anything above the minimum-energy curve is lofted; anything below, depressed. There is a family of curves crossing the minimum-energy lines that represents the lofting and depression options for the same propulsion system with the same payload. Thus, for a single design, one can shorten the range by lofting or depressing the trajectory or by using up excess energy by putting a "dogleg" (yaw) in the trajectory.

The maximum range achievable is a function of the propellant energy available, the amount of propellant used, and the ability to drop off used portions of the propulsion system in stages so that all of the dead weight of the original booster does not have to be carried over the entire distance. Short-range missiles (below 1,000 km) tend to be single-stage vehicles, medium- to intermediate-range (below 5,000 km) missiles tend to have two stages, and intercontinental-range missiles tend

Ballistic Missile Components



to have three stages. For a given design, one can trade payload for range. Essentially, for an SRBM, halving the payload increases the range by more than 150 percent. The Iraqis applied this method in extending the range of their Soviet-supplied Scuds. For an IRBM, lessening the payload to extend range is less desirable, since halving the payload adds only about 20 percent to the range. On the other hand, if an IRBM or ICBM can be flown to ranges only 80 percent of the design range, the payload can be uploaded (the number of RVs increased).

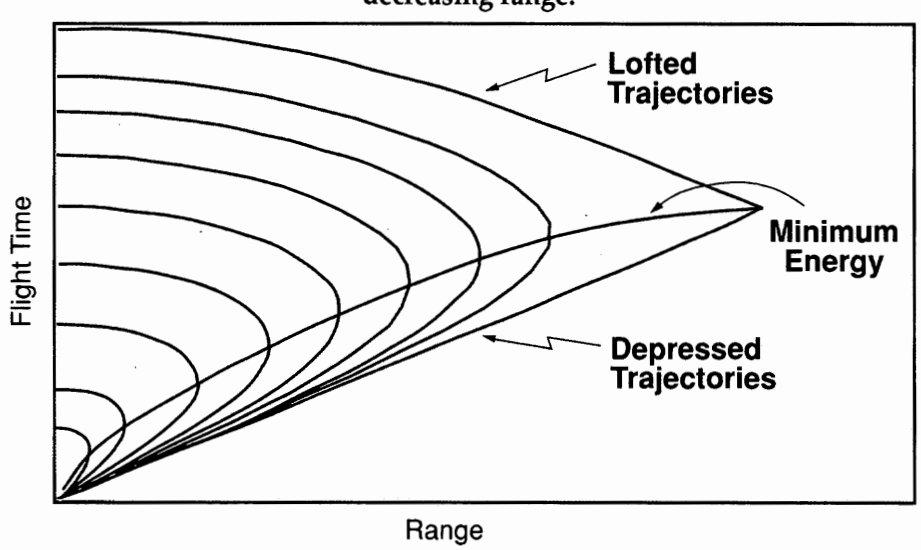
The range of a missile has important implications, both military and strategic. Generally speaking, it is more difficult to achieve accuracy at longer ranges than at shorter ones. As a result, the unsophisticated guidance systems used in many of the current longer range missiles restrict their use to the attack of large area targets. Strategic distances may range from tens of kilometers (in the case of Israel, for instance, which totally lacks strategic depth on several of its borders) to thousands of kilometers (as in the Sino–Indian confrontation). As developing nations acquire missiles with longer ranges, their options for attacking countries beyond their borders increase. Libya, for example, might be able to strike Paris or London in addition to Rome if it were to double the range of the Al Fatah.

There are other important parameters basic to the trajectories. The highest altitude achieved (the apogee) increases with longer range, and the entry velocity and entry angle (relative to the perpendicular) also increase. This means that a missile designed for the entry stresses at one range has the potential of breaking up if it is flown to a longer range where the higher entry velocity provides much higher aerodynamic deceleration loads. For the minimum-energy trajectories with a 1,000-km range, the apogee is only 250 km, while for intercontinental distances the apogee is 1,500 km or higher. Entry velocities increase rapidly with range and lofting. Entry angles decrease with range but increase with lofting.

The farther a missile travels, the more difficult it is to hit a target. Guidance technologies determine the accuracy of a missile. Acquiring advanced guidance systems has been one of the more difficult challenges for many developing nations. Protecting these technologies remains a focus of Western efforts to control the proliferation of missile systems into the developing nations.

Flight Time as a Function of Range

With respect to minimum-energy trajectories, lofting increases time of flight while decreasing range; depressing reduces time of flight while decreasing range.



Guidance improvements came slowly for the United States and Soviet Union as more advanced computers were developed and inertial references were improved. Today, however, open-market components are available to provide high-accuracy, low-cost targeting, previously considered difficult.

TECHNOLOGY STEPS

Advances in missile technology relate primarily to delivering more destructive power with greater speed and accuracy to a target at a longer distance. This must be accomplished while ensuring the survivability of the delivery vehicle both before launch and during flight, as well as ensuring that the cost and ease of storing and maintaining the missile before launch are consistent with military response needs and financial resources. To deliver larger payloads across greater distances, either the missiles must carry more propellant or more energetic propellants must be used. The propulsion technology entails fuel/oxidizing combinations with higher specific energy and materials for nozzles, exhaust cones, combustion chambers, valves, bladders, piping, and storage tanks that last longer under the increasingly corrosive environments of higher specific energy propellants.

Targeting accuracy may be improved in part by computer processing capability and pointing control measurements, but the quality of inertial reference and external positioning references can be much more limiting. Storage and maintainability are driven largely by propellant types. Survivability is a function of launch site hardness, launch site mobility or camouflage, and penaids. Penaids can be designed to (1) delay missile detection by degrading the track quality or making the track intermittent, (2) deny discrimination between multiple objects (or at least delay it enough to degrade the intercept probability), and (3) create an uncertain aimpoint location so that a defensive missile has a real probability of missing the incoming ballistic missile. The size of the warhead lethal radius and the destructive potential within that radius is the topic of Chapter Six.

From this simple beginning, a guidance system is normally added to allow specific targets to be hit in support of troop movements in tactical or theater campaigns. Gradually, longer range capabilities are acquired to allow targeting of troops, supplies, and populations deeper and deeper within an enemy territory, until finally a capability is achieved to strike targets across continents and oceans.

Ballistic missile developers generally begin with an unguided, liquid-propelled rocket with a simple HE warhead and no penaids that is launched from a fixed surface position. Such a system is vulnerable to counterattack, cannot hit anything more particular than an area, does little significant damage most of the time, and is expensive to maintain. On the other hand, it can terrify the population that it threatens.

Guided ballistic missiles can be categorized according to range. More than a third of the missile types in the longest range categories are submarine-launched ballistic missiles. As a country expands its capabilities into the longer range categories through either indigenous development or outside acquisitions, its options increase, but so too does its investment in money, people, and technology.

Propulsion Developments

Liquid propellants for missiles in the 150- and 300-km range categories are useful "learning tools" in the missile development industry. Only the Soviet Union and China have deployed intercontinental-range missiles that burn liquid propellants. The Iraqi designs are simply Scud variants, or multiple Scud variants that have been mated (Al Aabed). India's Agni has a solid lower stage and a liquid upper stage.

Propellants with higher specific energy are more difficult to implement. Hydrogen-/oxygen-propelled rockets and halogen-based liquid propellants cannot be acquired overnight, are difficult to maintain, are much more dangerous to handle, and have many materials problems peculiar to the containers, bladders, seals, valves, combustion chamber, nozzles, and other components. On the other hand, some chemical weapon (CW) materials have been used previously in the development of missile propellant systems, and the containment technology for these materials is related to

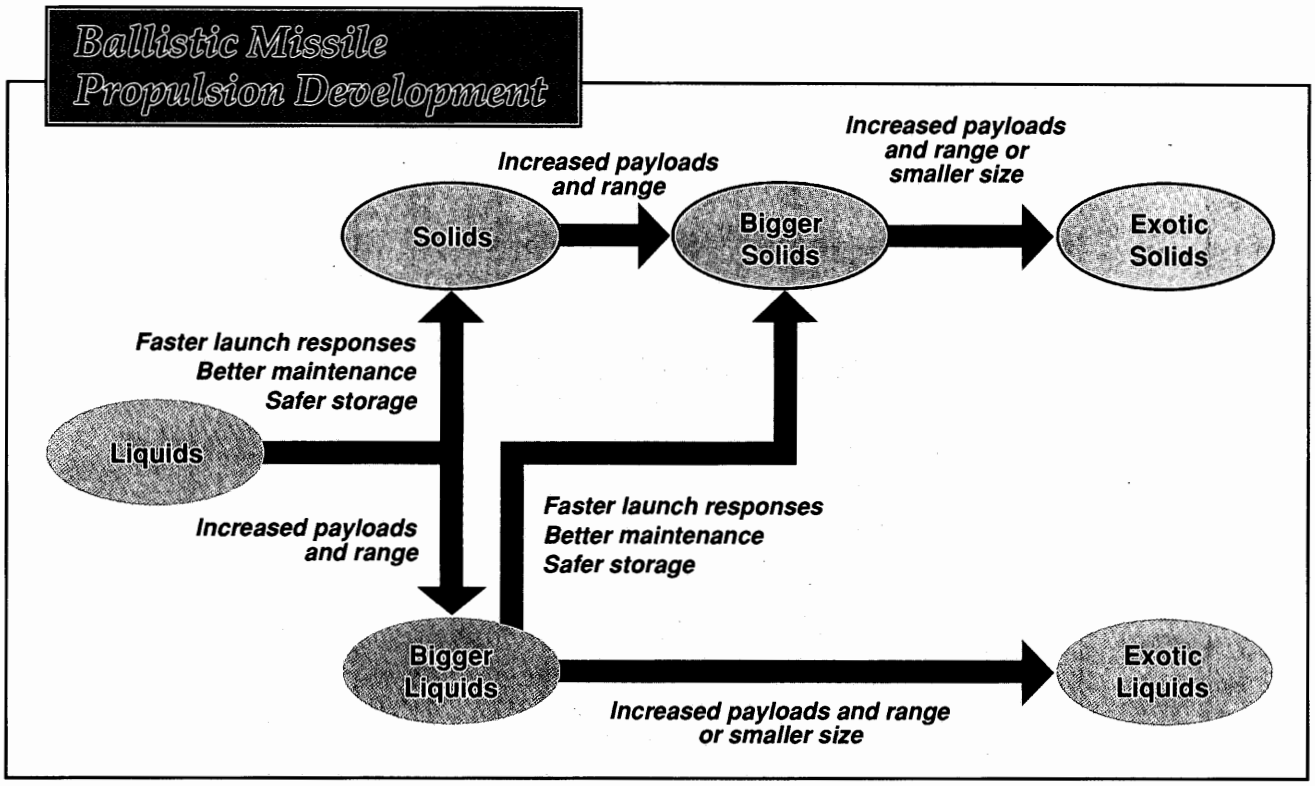
Ballistic Missile Production Development Range Categories (km)

Country	30+	120+	240+	480+	960+	1,920+	3,840+	7,680+
Argentina		Alacran			Condor 2			
Brazil		MB/EE–150 SS–150	MB/EE–300 SS–300	MB/EE–600	MB/EE–1000 SS–1000			
China		B–610	M–11	M–9		CSS–2, –5 CSS–N–3[S]	CSS–3	CSS–4
Egypt			Scud B	Scud C	Vector			
France		Pluton	Hades			S–3, –4 M–20[S]	M–4[S]	M–5[S]
India		Prithvi				Agni		
Iran		Iran–130	Scud B	Scud C				
Iraq			Scud B	Al Hussein Al Abbas	BADR 2000	Al Aabed		
Israel	Cricket			Jericho 1		Jericho 2		
N. Korea			Scud B	No Dong 1	No Dong 2			
S. Korea		NHK–1	NHK–2	NHK–3, –A				
Libya					Al Fatah			
Pakistan	Hatf 1		Hatf 2					
S. Africa				Arniston				
Taiwan		Green Bee		Sky Horse				
U.K.							A–3TK Polaris[S]	
USSR	SS–21 M1	SS–21 M2	Scud B Scud variant	SS–23[D]	SS–N–5[S]	SS–N–6[S]	SS–N–18[S]	SS–11, –17, –18, –19 SS–13, –24, –25, SS–N–8[S], –20[S], –23[S]
U.S.		Lance ATACMS		Pershing 1[D]	Pershing 2[D]		Poseidon[S] Trident C–4[S]	Minuteman 2, 3 Peacekeeper Trident D–5[S]

[S]Submarine-launched. [D]Destroyed as a result of the INF Treaty.

their use in exotic propellant combinations. CW developments are discussed in Chapter Six.

Propulsion technology is key to delivering more payload farther and faster. The original Chinese rockets were solid fueled, as are the unguided rockets used with multiple rocket launchers. Most ballistic missile manufacturers, however, switched to liquid-propellant boosters and upper stages to produce more accurate cutoff conditions. Reduced burn times for shorter ranges are also possible. The switch back to solid propellants requires significant technological advances, including thrust terminator mechanisms, computer-controlled maneuvers to use up excess fuel while retaining the same target point, or addition of a liquid-fueled, post-boost vehicle (PBV) to deliver single or multiple warheads. An alternative to using a liquid PBV for solid boosters would be to provide a maneuvering RV (MaRV) that would improve the targeting accuracy late in the trajectory through improved position knowledge received from external sources or from internal radar or optical homers. The benefit of solid propellants is



that they are easier to maintain, are safer to store, and can normally be brought up to launch readiness faster. This makes them better candidates for mobile launchers and for fast deployment in and out of hardened bunkers. On the other hand, liquid propellants are attractive alternatives for nations that have developed a petroleum refining capability. Solid-propellant systems require some additional technology to manufacture, but many useful formulations are available in the open literature.

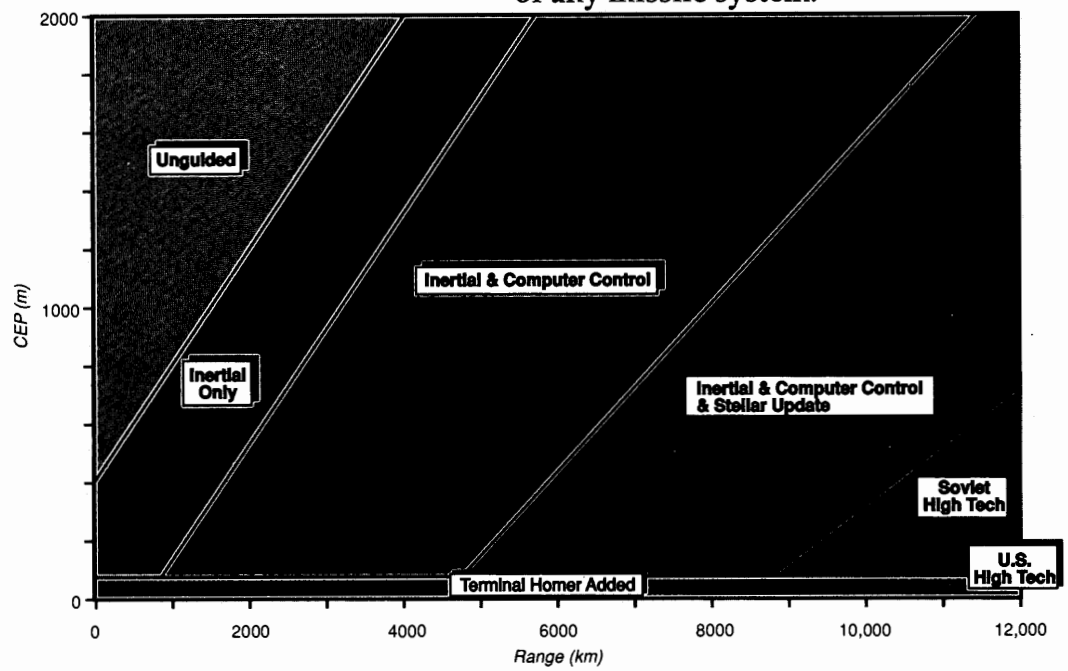
Guidance Developments

Improving targeting accuracy in any range category and then retaining that capability as larger, longer range missiles are developed constitute the next most important technology area. The targeting accuracy measure—CEP (circular error probable)—is the radius of the footprint within which the warhead will fall 50 percent of the time. Guidance technology can be divided into major regimes depending on CEP and range. In the unguided regime are the Soviet FROGs and the Iraqi variations of the Scud B that were outside the design regime of the Scud inertial system and thus essentially unguided. The inertial-only systems fall in a cluster in the second regime just beyond the unguided regime. The inertial-only band represents the conventionally available technology in gyroscopes and accelerometers to sense rotational and transverse motion. The wide range of CEPs for the inertial-only ICBMs is indicative of the improvements over time in gyroscopes and accelerometers by the Soviet Union, United States, and China.

The next step in the evolution of guidance technology is the addition of computer control for propellant use, nozzle vectoring, and other guidance functions; and command guidance or a star sensor to provide an external position reference. Soviet and U.S. high-technology position references are much improved over the developing nation capabilities. The stellar reference tends to be used only in the longer range sea-based or mobile missiles, which have sufficient time during propelled exoatmospheric flight to make use of the improved position reference data. Considerable discussion has been devoted to what might be accomplished at all missile ranges if the U.S. Global Positioning System (GPS) or its Soviet counter-

Trends in Guidance Technology Performance

Advanced guidance technology increases accuracy at greater ranges. Adding terminal homing increases the accuracy of any missile system.



part (GLONASS) were used to provide the in-flight position references. GPS receivers designed for nautical navigation and having accuracies from 8 to 30 m are available commercially at a cost of $2,000–$10,000. With some ingenuity, a missile developer in a developing country might be able to exploit this technology to significantly improve the accuracy of its missiles. *[Ref. 107]*

Much of the need for advanced accelerometers, gyroscopes, and external position references can be eliminated if the radar and passive infrared (IR) homing systems developed for aerodynamic missiles can be adapted to ballistic missiles for use after the major decelerations experienced during reentry. Representative of this capability are the short-range Soviet and U.S. systems. These missiles use radar/IR homing systems to locate the target and then engage simple devices like flaps to maneuver the vehicle to the target. The computer control problem still exists, but external position references and advanced inertial references are no longer needed; rather, homing sensors and maneuvering controls are now required. Radar seekers, IR seekers, and image comparator seekers are available on the open market, as are the high-technology engineers who know how to use them.

Survivability Developments

Survivability is the next important issue for ballistic missiles. Launcher survivability and in-flight survivability pose different technology challenges. Fixed surface installations are normally established to test rockets and to launch payloads into orbit. Since these facilities are vulnerable to a wide range of threats, the smaller ICBMs are usually rail, road, or ship mobile, while the larger ICBMs are buried in silos that have been made progressively harder over the years. To further increase the survivability of the strategic forces, submarine-launched ballistic missiles (SLBMs) have been developed to evade location and targeting systems. The mobile land-based missiles, on the other hand, have engendered surveillance systems to keep track of their movements. Simple hardened bunkers are used to protect these missiles when they are not deployed in the field and to introduce the element of uncertainty as to their whereabouts.

In-flight survivability is less well understood. Soviet missile doctrine is widespread throughout the world. Part of this doctrine includes material on radioelectronic combat, which addresses the passive and active electronic countermeasures appropriate to improve the survivability of missiles and their support facilities—launchers, surveillance and tracking centers, communications ground entry points, and command centers. The well-known Soviet anti-SDI book written by Velikhov outlines the five countermeasures appropriate to enhancing missile penetration against a coordinated defense: *[Ref. 99]*

- *Maneuvers*—to stress tracking and endgame aimpoint determination
- *Low observables (LO)*—to delay detection and degrade tracking by decreasing the signature or increasing the background clutter
- *Antidiscrimination*—to prevent or delay discrimination among multiple objects
- *Aimpoint deception*—to mask or shift the aimpoint in the endgame
- *Defense suppression*—to destroy interceptor launch facilities and support installations or the interceptor itself.

Several of these techniques have been demonstrated by the former USSR in tactical arenas.

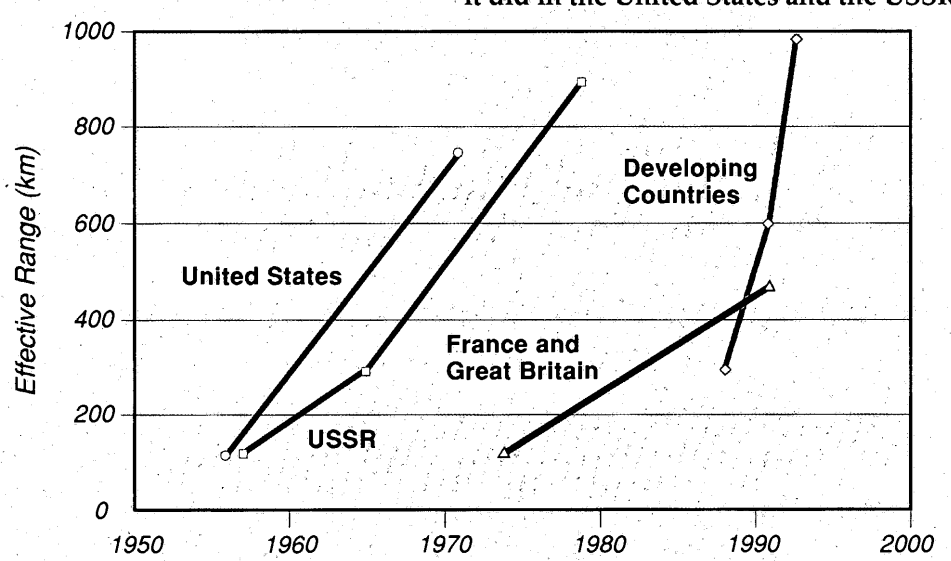
DEVELOPMENTAL PATTERNS IN TECHNOLOGY TRANSFER

The time flow of system developments has been explored to assess developmental patterns along the lines addressed earlier and to identify patterns of technology transfer. This section addresses the findings of that analysis.

Ballistic missiles fall generally into three separate regimes: strategic ballistic missiles, with ranges generally greater than 3,000 km; guided theater ballistic missiles, with ranges generally between 120 and 3,000 km; and unguided theater ballistic missiles, with ranges generally below 120 km. The strategic and guided theater ballistic missile regimes are discussed below. The short-range unguided ballistic missiles are beyond the scope of this report.

Comparison of Ballistic Missile Development

The development of missiles in developing countries is progressing at a faster rate than it did in the United States and the USSR.



Strategic Ballistic Missile Regime

The inheritance patterns for the strategic ballistic missiles within countries are fairly straightforward. There are, however, few obvious inheritances from country to country. For surface launchers from silos or road-/rail-mobile carriers, Soviet and U.S. capabilities parallel each other closely. For example, both pick up stellar reference position updates to improve targeting accuracy from mobile launchers at about the same time.

Chinese strategic ballistic missile programs appear to be stalled in the liquid-propellant stage and apparently lag the Soviet programs by about 15–20 years. An oversimplified projection would credit the Chinese with a silo-launched, solid-propellant missile capability in the early 1990s and a stellar reference capability after the turn of the century. The SLBM developments reflect a similar pattern except for the inclusion of the French, who lag the United States by about 12–18 years. Essentially, the Soviets and the United States have had a parallel development track. The Chinese and French have also had a parallel development track, albeit lagging the Soviets and the United States by about 15 years.

Guided Theater Ballistic Missile Regime

This same parallel and lag developmental pattern occurred with theater-range guided ballistic missiles. Here, however, an additional 15- to 20-year lag can be seen until the developing nations picked up the development cycle. The problem with the developing-nation cycle is that, once it has started, the range and guidance goals are achieved faster than they were with the earlier players.

Three missiles have undergone an apparent or unintentional franchising process. The Scud is the paramount example of this transfer process. After about 20 years of Scud B production, during which the Soviets had sold the missile to numerous countries, a process began through reverse engineering or a form of franchising that apparently resulted in a Scud manufacturing capability in North Korea. North Korea has even sold its version of the Scud B abroad and is reported to be establishing a manufacturing capability in Egypt, Iran, and Iraq. The Soviet upgrades to the Scud over that same 20-year period have apparently been produced indigenously in North Korea and Iraq, as exemplified by the Al Hussein, Al Abbas, and Al Aabed, one of which was used extensively in the Persian Gulf war. Iraq's capability to bring these longer range versions to fruition in the post-war environment is not clear.

In related technology transfer efforts, U.S. and Israeli missiles underwent reverse engineering in several countries. For example, Taiwan's Green Bee derives from the U.S. Lance; South Korea's NHK–1, NHK–2, and Hyonmu owe much to the U.S. Nike–Hercules; and South Africa's Arniston apparently shares some technology with Israel's Jericho 1.

With this kind of sudden interest in buying technology, China and Brazil entered the market. Each country received offers to begin delivery of two new missile systems by 1991, and China has already exported its M–9 and M–11. Brazil is reported to have had a test flight demonstration in Libya. Argentina offered its 1,000-km Condor 2 for sale but subsequently lost its financial backing to develop the missile. Libya, India, and Pakistan are actively engaged in their own theater-range guided ballistic missiles, which have advanced to the test phase.

Suddenly, the technology and components for theater-range ballistic missiles are available to any country with the commitment and resources to pursue them. The development process to produce a system integrating all of these technologies and components is still not easy, but the elements are there, and the developing country personnel are trained to understand them.

Liquid- and solid-propellant rocket technology is widely described in the open literature as a result of NASA efforts to develop boosters for scientific programs. Many engineers from other countries have been trained in the United States, Europe, or the Soviet Union and have worked on unclassified propulsion development programs before returning home. With the increasing demand for weapons in the oil-rich areas of the world, the skills of these engineers are in great demand.

TECHNOLOGY TRANSFER

Technology transfer can be accomplished in various ways—by buying products and reverse-engineering them, by hiring technical personnel from other countries to help develop indigenous capabilities, and by sending students to advanced industrial nations to gain the knowledge necessary to develop the desired technologies. All three methods are being used extensively by developing countries. This section examines (1) the availability of key components or subsystems needed to support missile production and (2) the possibilities for acquiring education and training for the people involved in missile production. The role of arms control and technology control in constraining missile technology transfer is discussed in the last section of this chapter.

Missile Component and Subsystem Products

A search through international defense news publications reveals a variety of products related to missile technology that are readily available to anyone with the funds to purchase them. The major components critical to missile development are listed below.

Structural design manuals for ballistic missiles are available in the open literature from NASA, European Space Agency (ESA), and other organizations involved in space programs. Details on the structural analysis programs can be acquired easily by any graduate student in the engineering sciences who requests them, regardless of his or her country of origin.

Liquid- and solid-propellant propulsion technology is readily available for ballistic missiles. Standard liquid propellants can be manufactured by any nation with a petroleum refinement capability. More energetic hydrocarbon-based liquid propellants are more difficult, but not impossible, to make. Exotic propellants like halogen-based fuels are not presently available. However, if a country develops a chemical weapons capability, it can potentially develop the containment, seals, and valve technology necessary for halogen-based fuels. Hydrocarbon fuel/oxidizer container, seal, and valve technology is commonly available on the open market.

The technology for solid-propellant fuels, although somewhat more complicated, is readily available. Standard solid-propellant formulations of 20 or 30 years ago are described in the open literature, and some of them can be manufactured from standard materials in small batches in a rudimentary manner. Many of these propellants are the same ones used in unguided multiple rocket launcher missiles, which explains much of the widely varying range capabilities for missiles of similar diameter and length. Although finesse is

Missile Technology Availability

Technology	Easy To Obtain	Difficult To Obtain
Missile structural designs	X	
Propulsion (Liquid)		
Standard hydrogen-based propellants	X	
Halogen-based propellants		X
Fuel tankage, seals, and valves	X	
Combustion chambers and nozzles	X	
Thrust vector vane/flap	X	
Thrust vector nozzle		X
Propulsion (Solid)		
Standard hydrocarbon-based propellants	X	
Exotic propellants		X
Propellant packaging designs	X	
Guidance		
Inertial—standard gyros and accelerometers	X	
Inertial—cryogenic gyros and precision accelerometers		X
Radio command position updates	X	
Stellar reference position updates	X	
GPS/GLONASS position updates	X	
Terminal homing		X

certainly desirable in developing better solid-propellant formulations, the "brute force" approach can yield an effective product, notwithstanding the problems associated with quality control, safety, and other limiting factors.

The primary limits on propulsion system technology are the combustion chamber and nozzle. The solution to this problem, which involves both thermochemical and thermodynamic processes, is the most difficult for which to develop an indigenous production capability. There are numerous developed countries, however, with companies competing to help solve the problem for others.

Thrust vector controls are important for improving the targeting accuracy. Simple flaps are typically used on short-range ballistic missiles that have a maneuvering capability. In these designs, the tradeoff between spin stabilization and maneuvering simplicity is key. Aerodynamically maneuvering reentry vehicles can be used on longer range ballistic missiles, but their implementation tends to require a series of high-technology solutions not readily available in developing countries.

Guidance systems are perhaps the most sophisticated technology required for missile development. Structure, propulsion, and warhead subsystems can be engineered through sheer brute force, but knowing where the missile is and where it is intended to go—and then guiding it to that point—requires finesse.

The accuracy of the knowledge of motion history is controlled by the quality of the sensors used to measure translational and rotational motions, each in three dimensions. The accelerometers used to measure translational motion have evolved to the point where they can now be produced on silicon chips. The gyroscopes used to measure rotational motion on missiles derive from the large devices used to orient stabilization and navigation instruments on ships. Modern gyros can be as small as a roll of 35-mm film and can sell for as little as $100. The cryogenic gyro used in long-range ballistic missiles, although superior in performance and considerably more expensive than these simple devices, is not necessarily better for all missile applications. New tuning-fork gyros measure the rotational motion differently but can achieve similar accuracies. Efforts are under way to integrate them on a single silicon chip and reduce their cost to a few dollars so that they can be used in multiple applications like automobile steering and braking functions. In the next 5 years, there will be a significant improvement in inertial guidance system performance for missiles. *[Ref. 106]*

To overcome the natural drift from the inertial inaccuracies, early missile guidance technologists began exploring methods to provide in-flight position to reset the inertial system. At first, external radars or other sensors were used to derive missile position, and guidance corrections were made. Long-range missiles presented additional problems since they did not remain in the sensors' field of view for the entire flight. Star sensor technology (developed for satellite applications) was adapted to provide accurate position references when the missile was outside the atmosphere. Although this technique is now in widespread use by the high-technology countries for long-range missile guidance, it is not practical for missiles that stay within the atmosphere for most of their trajectories. More recently, there has been talk of using the GPS or GLONASS to provide continuous position updates. Moreover, commercial GPS receivers developed for marine navigation have position accuracies down to 8 m and can cost as little as $2,000. *[Ref. 107]*

For terminal guidance, a range of technologies is presently available. The antiradiation homing missile, flying a typical ballistic trajectory, seeks out radar or communication link radiation sources and homes in on them. Semiactive radar uses a separate radiation source and picks up the reflected signal on the missile. The TV or IR comparator technique is another proven approach, and the cost of these devices has recently plummeted—some to as low as $1,000. Small sensors (about the size of a 6-ounce juice glass) are now available commercially that essentially create images of what they see and then compare them with a stored array of aspect-angle variant images of the desired target. If a match to some predetermined level is achieved, the missile homes on that target. *[Ref. 108]*

Penaids are perhaps the least considered and most interesting technologies available to the developing countries. Numerous unclassified books are available on electronic countermeasures.

Soviet military doctrine, which is used widely throughout the world, emphasizes the importance of radioelectronic combat; entire battalions are dedicated to this form of warfare. Some of the major classes of penaids are discussed in Velikhov's Soviet anti-SDI book. Although some of the penaids from these sources are beyond the developing nations' and even U.S. and CIS resources, many of the concepts have simple versions that can be very effective in low-technology defensive environments. *[Ref. 99]*

Education and Training in Missile Technology

People are one of the best resources for transferring technology. To undertake an indigenous effort in any technology area, it is essential to understand the design and manufacturing capabilities needed to support the technology. This can be accomplished in part by sending students to study engineering, science, and mathematics at the universities of industrialized countries. In addition, it is important to bring in experienced design and manufacturing personnel to provide training in areas not covered in standard curricula. A viable missile development program requires not only engineers and scientists, but also machine tool operators, welders, wire wrappers, optics grinders, and a myriad of other manufacturing specialists needed for medium- to high-technology systems. Although the products associated with these disciplines can often be purchased at the component level, the availability of foreign parts or components is seldom reliable during wartime.

Education

As a matter of policy, the United States, Europe, and the Soviet Union have been providing technical education to developing countries for more than 30 years. More than half of the students enrolled in U.S. technical graduate schools are foreign born. Some of these students have emigrated to the United States with their families and have taken advantage of the local subsidies and loans available to minorities. Many more are subsidized by their native countries, some to study specific technologies. The countries that have taken advantage of U.S. educational opportunities in aeronautical, astronautical, and nuclear engineering—all key areas of missile technology proliferation—include China, Egypt, India, Iran, Iraq, Israel, Lebanon, Libya, Pakistan, Saudi Arabia, South Korea, Syria, Taiwan, and Turkey. Note that many of these countries are either major buyers or emerging suppliers of missiles.

Training

Once a country has assembled a cadre of scientists and engineers, the next step is to provide them with formal training in the specific technologies required for missile development. This entails bringing in experienced designers and manufacturing specialists to aid the newly educated engineers in understanding the details not provided in the classroom or in entry-level jobs. For example, Professor Tsien from the California Institute of Technology returned to his homeland in China in the 1950s and eventually became the director of its space program.

The other dimension of providing and enhancing indigenous training efforts is the hosting of foreign experts by developing countries. Foreign scientists and engineers have added greatly to military programs by their direct design efforts and by training scientists and engineers. In many cases, technically advanced countries have sought to enhance relations with developing countries by providing technical experts, military advisors, and trainers. The Soviet Union did this extensively during the cold war through friendship and cooperative agreements with developing countries.

The United States and Soviet Union began their own missile programs in much the same way, although under quite different circumstances, following World War II. Both countries returned from the war with an extensive group of experts in German missile technology, including scientists, engineers, machinists, welders, casters, metalworkers, and other manufacturing specialists.

Outside expertise is often obtained as an outgrowth or byproduct of missile programs that have been franchised or subsidized by third-party nations. For example, the Soviet Union franchised Scuds to some of the Warsaw Pact countries, China, and North Korea, which in turn have provided technical help to Iran, Iraq, and Egypt to start production lines of their own for one or more of these missiles. The United States has subsidized to some extent (directly or indirectly) the Israeli Nimrod, the South Korean NHK–1 and NHK–2, the Taiwanese Green Bee, and a number of other

missiles developed throughout the world. Israel has conducted joint tests with South Africa in a cooperative effort to develop the Jericho missile.

Iraq's Al Hussein missile has been identified at one time or another as the Soviet Scud B and as the Brazilian SS–300. Technical assistance on the Al Hussein has been attributed to China, Egypt, and France; various other designs for the Al Hussein have been ascribed to East Germany, Libya, and North Korea.

Reserve General Hugo de Oliveira Piva of Brazil headed a 21-man engineering group working in Iraq to develop ballistic missiles with ranges of 600 and 1,000 km. In the fall of 1990, just before the outbreak of the Persian Gulf war, General Piva pulled his group out of Iraq. He has since offered those same engineers to Iran.

Piva is backed by the Orbita missile consortium, whose MB/EE SRBM series is believed to incorporate a U.S. guidance system derived from sounding rocket development programs. Orbita is also reported to be working with Libya and is said to have test fired a missile with a range of about 650 km in 1988. Avibras, also of Brazil, has been developing a similar series of missiles based on the Scud B but using a Chinese guidance system.

Argentina, Egypt, and Iraq formed a consortium to build the 1,000-km Condor 2. Iraq eventually dropped out, and Egypt soon followed suit, after which Argentina found it could not shoulder the development costs alone. A spinoff called Badr 2000 in Iraq and Vector in Egypt is reportedly under development. Libya is developing the Al Fatah or Iltesslot missile with help from Brazil, China, and Germany.

When the U.S., Soviet, and European missile investments peaked in the early to mid 1980s, these countries suddenly had a surplus of manufacturing capability and an excess of trained people, many of whom had spent 10 to 30 years of their life designing and building missiles. Without jobs but with families to support, these people offered their services to the highest bidder. It is not surprising, then, that the sudden proliferation in missile production began about 1987. Today, with the continuing curtailment of the U.S., Soviet, and European missile programs, an even larger supply of trained missile engineers and technicians is available. The problem is in how to employ these people in other industries that offer comparable salaries and job satisfaction.

ARMS AND TECHNOLOGY CONTROLS

Arms control is often considered a panacea for reducing arms races and mitigating the danger of military confrontation. With the completion of the Intermediate-Range Nuclear Forces (INF) and Strategic Arms Reduction Talks (START) agreements, the arms control approach indeed has resulted in a reduction of missile inventories, thereby contributing to the general easing of international tensions that were prevalent during the cold war. However, most arms control regimes have been superpower or alliance oriented. Little has been effected to date to stem arms races or missile proliferation in the countries that make up the developing nations.

A number of arms and technology transfer regimes that provide a framework for addressing the missile proliferation issue have been initiated in recent years. The regimes require greater participation by major countries and an increased priority by their policymakers before they can ensure more effective implementation of their control guidelines. Only if these requirements are met can such efforts effectively stem missile system and component proliferation. Even then, future deployments of antimissile systems may be necessary to deter and defeat missile strikes launched in various scenarios.

Formal Arms Treaties

Few of the existing arms control treaties significantly constrain missile proliferation. The two in which constraints are most prominent are the INF and START treaties. The former, signed in 1987 by the United States and the Soviet Union, requires destruction, within 3 years, of each party's ground-launched ballistic and cruise missiles with ranges between 500 and 5,500 km, their launchers, and associated support structures and support equipment. Subsequently it was discovered that, prior to treaty signature, the Soviets had covertly transferred some SS–23 missiles to their (then) Warsaw Pact allies of East Germany, Czechoslovakia, and Bulgaria, but these have been or are in the process of being destroyed. No other

transfers of missiles subject to the INF Treaty are known to have occurred. However, several other countries—including China, Israel, and North Korea—are known to possess missiles with ranges that are covered in the INF Treaty. If the accord were broadened to a multilateral agreement, and if those countries signed and implemented it, these missiles would be subject to treaty requirements for destruction. No such effort has been attempted by the United States or the Soviet Union.

The START agreement, signed by the United States and the Soviet Union in 1991, involves a complex set of reductions and limitations affecting each party's strategic nuclear ballistic and cruise missiles and strategic bombers. It prohibits the transfer of strategic offensive arms to third countries, except in cases where there are "existing patterns of cooperation." This condition in practice applies only to transfers of some U.S. strategic arms to the United Kingdom. No other countries have had strategic missiles transferred to them by the United States or the Soviet Union.

The 1988 Ballistic Missile Launch Notification Agreement requires each party to notify the other, at least 24 hours in advance, of the planned date, launch area, and area of impact for any launch of an ICBM or SLBM. As with the INF Treaty, no attempt has been made to broaden this into a multilateral accord.

The Treaty on Conventional Armed Forces in Europe (CFE), signed in 1990 by 20 states in Europe plus the United States and Canada, has an indirect impact on missile proliferation. Although conventionally armed missiles are not subject to the treaty, multiple rocket launchers (MRLs) are included in the definition of artillery systems that are subject to treaty ceilings. The Soviets might achieve some of their reductions in their European artillery holdings through limited exports of MRLs. (Most reductions are required to be accomplished through destruction.) This can contribute to missile proliferation because development of artillery rocket systems can provide a path to development of surface-to-surface missiles, as was the case in Brazil and Iran.

Reductions of other equipment limited under the CFE treaty (including tanks and armored combat vehicles) might result in an upsurge in arms exports from CFE participants to developing countries. This increased military capability might provide an additional incentive for those developing countries to acquire other non-CFE-limited advanced weaponry such as ballistic missiles, enabling them to engage in a broad range of armed conflict.

Informal Arms and Technology Control Approaches

In recent years, a number of initiatives have sought to address the proliferation issue through informal agreements, confidence-building measures, and restrictions on exports of key technologies. Regional efforts have been largely unsuccessful in limiting missile proliferation, but there is a basis for future expansion to more effectively address the issue. For example, India and Pakistan recently agreed to several confidence-building measures, including agreements prohibiting attacks on each other's nuclear facilities and requiring advance notification of military exercises. Pakistan has sought formal arms control talks with India, but the latter has not accepted the proposal.

A forum for discussion of regional issues—including proliferation—has been envisioned as part of the Middle East peace process, but actual negotiation of these issues seems to be some time away. Egypt has proposed the elimination of all weapons of mass destruction in the Middle East, but the proposal seems to have generated little interest. Technology controls have been forcibly imposed on Iraq in the aftermath of the Persian Gulf war.

Technology controls are assuming greater importance in attempts to control missile proliferation. The Group of Five (United States, Soviet Union, United Kingdom, France, and China) and the Group of Seven (United States, United Kingdom, France, Italy, Germany, Canada, and Japan) have discussed this issue within the past year and intend to pursue it to establish greater control over arms transfers, including missile systems. The Coordinating Committee on Multilateral Export Controls (CoCom)—established in the early cold war years by NATO member states, Japan, and Australia—has focused its attention on controlling exports of sensitive goods and technology to Eastern bloc states; in the wake of the cold war, CoCom is just beginning to refocus its attention onto developing weapon proliferators. Partici-

pation in observing CoCom restrictions is voluntary, and the member country governments are responsible for CoCom verification and enforcement mechanisms. This has sometimes led to interagency and bureaucratic conflicts, resulting in an uneven application of export restrictions.

Perhaps the technology control approach most relevant to the missile proliferation issue is the Missile Technology Control Regime (MTCR), created in 1987 by the Group of Seven. The regime applies controls to technologies that would contribute to the capability of unmanned delivery of a payload of at least 500 kg across a distance of at least 300 km. It applies to ballistic missiles, space launch vehicles, and sounding rockets. MTCR membership has grown from 7 nations at its inception to 18 countries (Spain, Australia, Belgium, Luxembourg, the Netherlands, Denmark, Austria, Sweden, Norway, New Zealand, and Finland all have joined subsequently), with 2 others (Portugal and Israel) indicating their intention to join soon, and 2 more (Switzerland and the Soviet Union) effectively participating as de facto members through their adoption of export regulations similar to the MTCR's.

In deciding on an export license request, MTCR restrictions apply for two categories of technologies: those for which transfer is denied, and those that are subject to case-by-case review with end use/no retransfer assurance in order to prevent contribution to "nuclear-capable" missiles. The regime is not bound by treaty provisions. It has no verification provisions, relying instead on disclosure of information from government to government.

The MTCR is not without some significant weaknesses. It does not include all the major suppliers of missile technology, notably China (recent missile exports of which have caused concern to U.S. policymakers) and North Korea (which has an indigenous missile production capability). Moreover, the MTCR has a poor record of enforcement by several key adherents. Each member country has implemented the regime in different ways, and competing political and economic interests will likely interfere with effective implementation. In addition, the MTCR range and payload guidelines are not necessarily relevant limits for a number of regions where adversarial states are separated by relatively short distances; a Western definition of a "tactical" missile can be misleading for geographically proximate states that would perceive the same missile as "strategic." The MTCR, like any export control regime, must surmount the difficult problem of dual-use technology, particularly when exports of a certain technology play an important role in a country's economic well-being.

Finally, many missile technology-recipient countries are opposed to the MTCR regulations on the grounds that the regime is inherently discriminatory. They will seek to circumvent the regime wherever possible if they do not already possess the technologies that MTCR attempts to control.

Despite these weaknesses, MTCR does appear to have been effective to some degree. No other barrier of consequence to missile proliferation has been erected, and a number of countries (e.g., Pakistan, Argentina, Iran) appear to be stalled in making progress with their missile programs, due in large part to diminished foreign technological assistance that they need in order to develop and deploy longer range ballistic missile systems with high accuracy. *[Refs. 39, 109, 110]*

Chapter Six

Ballistic Missile Warhead Technology

Warhead technology transfer, in its earliest manifestations, dates back to ancient times. Chinese gunpowder and rockets emerged in the West almost as soon as they became known. Chemical and biological poisons have been available for thousands of years.

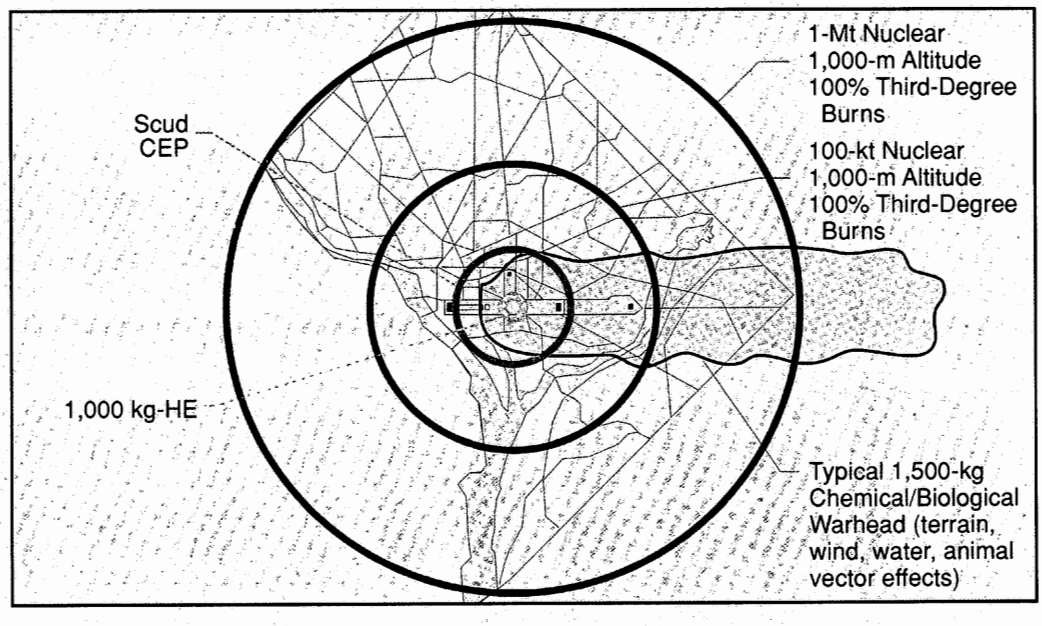
Explosives of almost any type can be purchased today on the arms market as part of weapon systems. The developing countries provide a large market for legal and illegal warhead sales. In addition, the technology required to manufacture explosives is generally well known and is relatively easy to develop or to acquire on the open market. Ballistic and cruise missiles are sold together with their warheads—in some cases, complete with engineering drawings. Conventional warheads for ballistic and cruise missiles can thus be copied or designed with little difficulty.

Nuclear Weapons. Developing countries have shown considerable interest in nuclear weapons. Because such weapons are designed to inflict mass destruction, they serve as an "equalizer" for smaller nations vis-a-vis their more powerful neighbors. The design, construction, and packaging of a nuclear warhead are discussed later in the chapter.

Chemical Weapons. Chemical weapons share some of the characteristics of mass destruction attributed to nuclear weapons. Depending on the circumstances, chemical weapons can inflict casualties ranging from a few to hundreds of thousands. Even against a well-prepared population under unfavorable weather conditions, chemical weapons may be more deadly than conventional munitions. Used against unprepared populations under predictable weather conditions, chemical weapons can have devastating effects.

Biological Weapons. Biological weapons could approach nuclear weapons in terms of lethality. And unlike chemical agents—which even

Comparative Kill Radii for Different Warheads



in their most persistent form might pose a continuing hazard to large numbers of people for only a few weeks—biological agents like anthrax spores may persist in the soil in deadly form for decades.

WARHEAD PERFORMANCE COMPARISON

The two primary goals of most warhead programs are (1) improved kill of specific targets and (2) increased devastation from a single warhead delivered on an area target. The first goal, and to a lesser extent the second, are tied to the missile guidance capabilities discussed in Chapter Five. The areas of destruction of high-explosive (HE) and nuclear weapons and the areas of contamination of chemical and biological weapons can easily be compared. For limited-area targets, the closer the missile approaches the target center before detonating, the greater the likelihood of a kill.

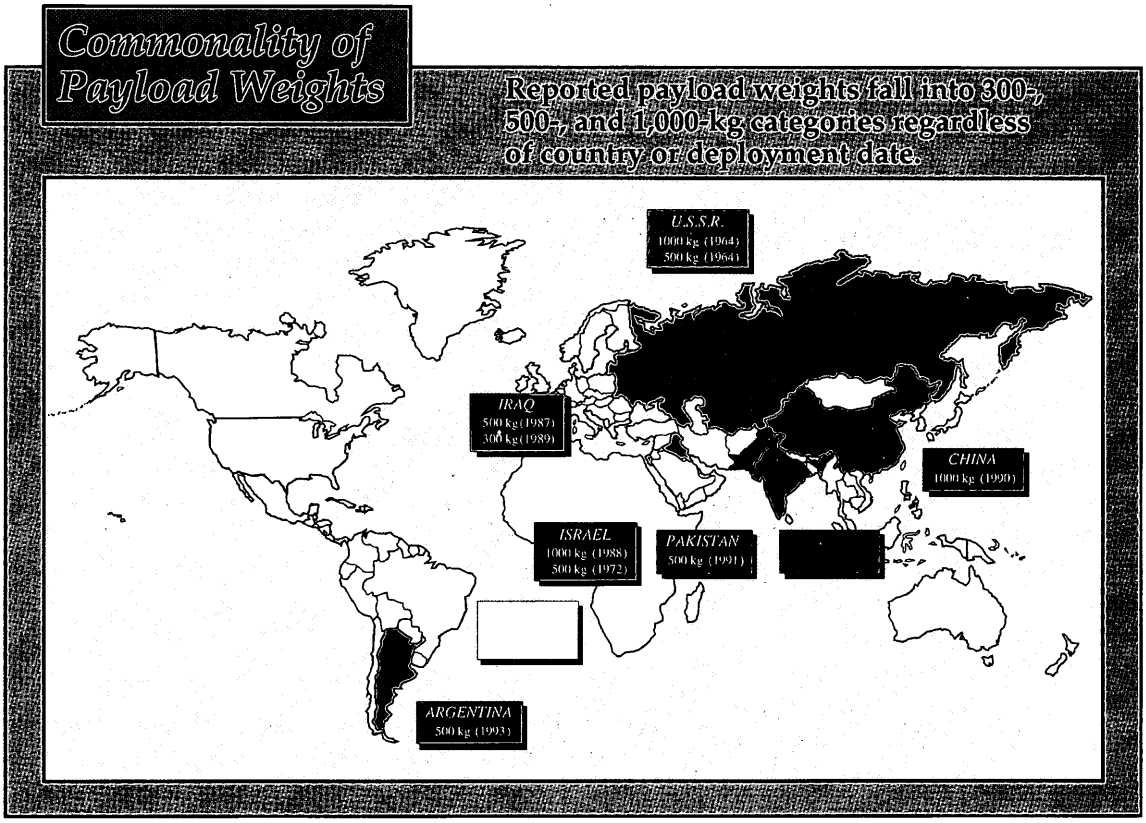
Targeting accuracies are expressed in terms of circular error probable (CEP), the circular area about a desired aimpoint within which one-half of the missiles fired at that target will fall. For a Scud B with a 450-m CEP, a 1,000-kg warhead is insufficient to produce surface kill for all objects within the CEP circle. If the intent is to crater an airfield or exact the maximum number of casualties in a tactical troop location, the 50-m CEP of the latest Soviet Scud variant is needed to ensure that the associated submunitions will be effective. The Scud runway penetration warhead could contain forty 12-kg submunitions, while the antipersonnel warhead could contain one hundred 5-kg submunitions. Of course, nuclear, chemical, and biological (NBC) warheads have a much wider area of destruction and thus provide a sure kill with much less target accuracy. However, such weapons may not be desirable if the intent is to enter the target region after the attack since some residual NBC contamination can linger at dangerous levels for long periods of time.

If the objective is simply to inflict broad devastation on military deployments or civilian replenishment facilities, NBC warheads can provide that capability. Tactical applications against point targets are also possible but require precise knowledge of various conditions such as target location and weather. The areas of devastation for most typical NBC weapons exceed the Scud CEP. All these NBC weapons can reflect the peculiar offset footprint of a wind-driven kill vector. Yields of current nuclear warheads for missiles range from 0.1 to 1 Mt. A chemical agent like tabun and a biological agent like anthrax may provide a side-shifted oval or complex kill patterns since a multitude of parameters affect their spread and persistence. Anthrax, for instance, can spread further by reinfection. In fact, for some biological weapons, the secondary vector can move back into the territory of the originating country. These comparatively large NBC kill areas have obvious advantages if the principal criterion is devastation.

PAYLOAD WEIGHTS

The payload weights associated with the various weapon systems available in the developing countries tend to fall into three categories: 300 kg, 500 kg, and 1,000 kg. These groupings were probably caused by factors such as target destruction requirements, desired range capability, and availability of packaged warheads. Generally, payloads of at least 300 kg are needed for tactical and theater missions against vehicles and personnel. The next category, 500 kg, includes submunitions and certain other kinds of specialty conventional weapons. Submunitions require a payload of at least 500 kg to distribute the destructive effects needed for missions such as antipersonnel, incendiary destruction, minelaying, and runway cratering. Deep penetration or fuel-air explosives generally require a payload of at least 750 kg to ensure maximum effectiveness. At 1,000 kg, the upper category, the warhead can accommodate a low-technology nuclear weapon with a yield of about 20 kt or a more sophisticated weapon up to about 1 Mt, chemical or biological agents sufficient to produce casualties in the hundreds of thousands, and HE charges that include virtually all submunitions options and specialty applications that might be encountered.

Although submunitions can be deployed with a 500-kg payload, the additional mass of a larger 1,000-kg payload provides increased lethality and mission flexibility. Typical submunition payloads



Typical Payload Weights

Warhead Type	Weight (kg)
High Explosive	
Submunitions	500–1,000
Special applications	750–1,000
Nuclear	
Theater surface targets	300–500
Silo/bunker-busters	
High-tech guidance and control	300–500
Low-tech guidance and control	500–1,000
Chemical and Biological	
Tactical	300–500
Theater	500–1,000

include general-purpose HE cluster bomblets, runway penetrators, armor penetrators, combined fragmentation/incendiary munitions, mines, and smoke munitions. Generally, all of these submunitions and more are available on the open market and are advertised in various trade papers and magazines. For example, Raketen Technik GmbH (RTG), a German firm, placed an advertisement in the fall 1991 issue of the *International Defense Review* in response to the extensive publicity that submunitions received during and after the Persian Gulf war.

The 500- and 1,000-kg payloads already established for specialty HE and nuclear warhead options are also appropriate for chemical and biological warheads. These payloads provide good performance for chemical and biological weapons.

HIGH-ENERGY EXPLOSIVE WARHEADS

The technology steps for HE warheads are relatively straightforward. Conventional HE is readily available, and special HE warhead designs have been widely studied for many applications. Conventional HE payloads are available for virtually all of the ballistic missiles of interest. In addition, several countries are known to have available blast fragmentation warheads for use with their cruise missiles (e.g., Chinese Silkworm, Iraqi FAW, Israeli Gabriel) or submunitions (e.g., French Exocet, German Kormoran).

Short-range ballistic missiles with antiradiation homing devices have much better targeting accuracies and can be deployed with a variety of special warheads and submunitions for use against specific targets. The 500-kg HE warheads can be semi-armor-piercing, blast fragmentation, earth penetration, or fuel-air-explosive weapons. The blast fragmentation and fuel-air explosives are more useful against personnel, whereas earth penetrators allow destruction of buried facilities and bunkers.

NBC WARHEAD TECHNOLOGY

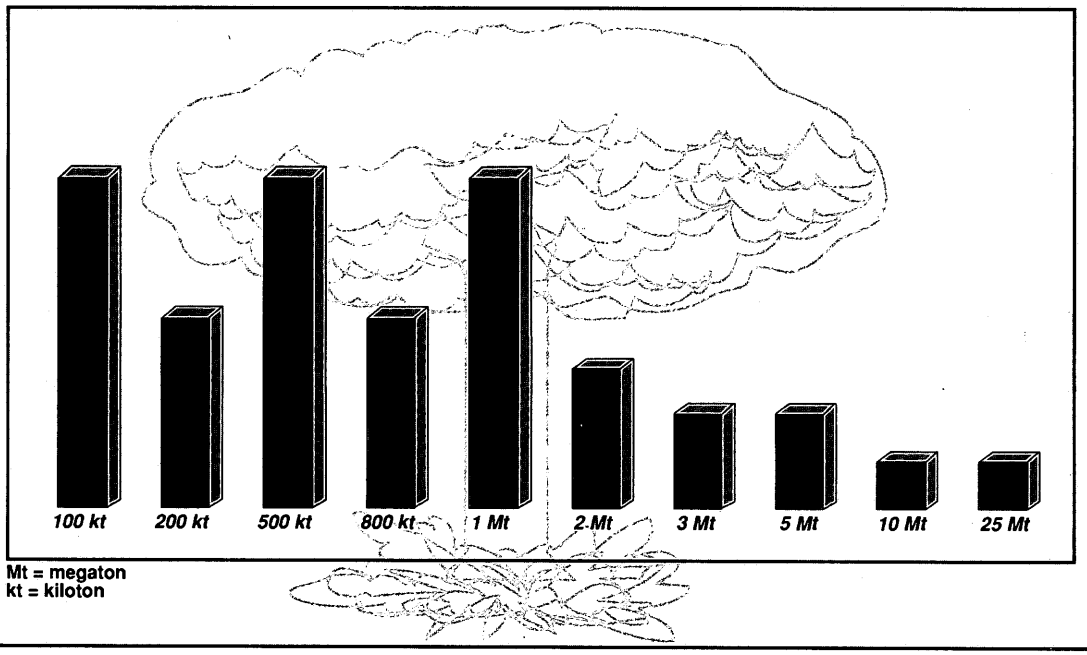
Nuclear Warhead Technology

In 1945, the United States tested an atomic device in New Mexico, thus ushering in the nuclear age. Several months later, in an effort to end World War II, U.S. forces detonated two primitive fission bombs over Hiroshima and Nagasaki, resulting in about 150,000 immediate casualties. These bombs were large devices that were delivered by heavy bombers. Since then, the capability to package a nuclear weapon in a small warhead has advanced dramatically. Also since 1945, five other countries have tested nuclear devices: the Soviet Union (1949), the United Kingdom (1952), France (1960), China (1964), and India (1974). Given the widespread knowledge of basic nuclear physics and weapon engineering, and the existence of commercial nuclear programs to provide the fissionable materials, a number of other nations could build nuclear weapons, should they choose to do so.

Nuclear warhead weights depend upon weapon design and yield. Historically, the United States and the Soviet Union have produced nuclear warheads weighing as much as several thousand kilograms and having yields of as much as 25 Mt. However, most of their current nuclear warheads have yields from 20 kt to 1 Mt and weigh no more than 1,000 kg. Due to improvements in the targeting accuracy of ballistic missiles, any country that can obtain the materials and expertise required to build a nuclear device can develop a credible nuclear threat. In fact, those countries that are considered to be seriously attempting to develop or acquire nuclear weapons all have missiles

Reported Ballistic Warhead Yields

Modern warhead yields are 1 megaton and below because of improvements in accuracy.



in place or on order that can accommodate 500- to 1,000-kg nuclear payloads.

To develop nuclear weapons, a country would need sufficient fissile material, the proper high explosives to create a supercritical mass, high-speed switches and capacitors to detonate the high explosives correctly, neutron initiators to start the fission chain reaction, neutron reflector material to assist in maintaining the chain reaction in the fissile core, and—most important—sufficient manpower with fundamental knowledge of nuclear physics and experience in various disciplines of engineering. According to U.N. estimates, Iraq employed up to 7,000 scientists and engineers—mostly their own citizens who were educated in U.S. and European universities—and up to 13,000 technical support personnel in its nuclear weapon research program during the 1980s.

Other developing countries have also established an infrastructure of technical expertise, albeit perhaps not so extensive as that of Iraq. In addition, a number of reports suggest that nuclear experts may be available for employment from the former Soviet Union. Faced with meager wages (equivalent to about $5 to $7 per month) and pensions, numerous nuclear scientists and engineers have reportedly already departed the newly formed independent republics to accept lucrative positions in developing countries. As yet, however, massive movements of technical personnel have not been confirmed.

The current upheaval in the former Soviet Union may provide additional choices to a country in the orientation of its nuclear weapon development program. Rather than mining indigenous uranium ore (assuming that it is available) and developing extensive, time-consuming, and costly enrichment facilities, a country with nuclear ambitions might attempt to purchase (or steal) existing nuclear warheads from one or more of the former Soviet republics. Approximately 15,000 tactical nuclear weapons are deployed among 86 former Soviet military divisions. Several million dollars might be enough to surreptitiously purchase a few such weapons, as compared to the several *billions* of dollars required to initiate a full-scale nuclear weapon development program. During the late 1980s, Iraq reportedly invested $4 to $8 billion in enrichment technology. *[Refs. 111, 112]*

Several unconfirmed reports suggest that sales of ex-Soviet nuclear materials already appear to be occurring. It is reported that a uranium shipment and a plutonium "sample," both of Soviet origin, were seized by Swiss and Italian authorities, respectively, in late 1991. The uranium may have been destined for the Middle East. The Italians also reported finding documented evidence of the completed sale of nuclear artillery shells from a military base in Irkutsk, Russia. In fact, the Moscow-based CHETEK Corporation, recently founded through the cooperative efforts of the former USSR Ministry of Atomic Power and Industry and the All-Union Research Institute of Experimental Physics (Arzamas–16), has advertised "peaceful nuclear explosives" as a product line. CHETEK appears to be able to acquire and possibly sell sensitive nuclear materials and devices, associated equipment, and scientific support. *[Refs. 50, 72, 113]*

On the other hand, if a developing country desired to possess complete nuclear production capabilities, it could—as Iraq started to do—build enrichment facilities to separate fissile ^{235}U from ^{238}U, the predominant isotope in uranium ore. Enrichment technology options include electromagnetic isotope separation, gaseous diffusion, and gas centrifuge separation. In the first process, ionized uranium-laden gas is placed in a calutron, which then separates ^{235}U from ^{238}U by means of an electromagnet. Although information is readily available on calutron design, the primary power requirements are formidable.

An enrichment plant containing hundreds of calutron units and designed for production of 50 kg of 90-plus percent enriched ^{235}U per year would require 50 MW of prime power, a sizable amount for a developing country to dedicate to a single facility. Gaseous diffusion and gas centrifuge separation also require hundreds of units with substantial power requirements if reasonable ^{235}U quantities are to be produced. Gaseous diffusion is based on the principle that $^{235}UF_6$ gas diffuses at a higher rate through a series of porous barriers than $^{238}UF_6$. In gas centrifuges, the uranium hexafluoride gas is injected into a cylinder; the gaseous isotopes separate when the cylinder is spun at high speed. *[Ref. 77]*

Current and Potential Nuclear Nations

Established Nuclear Powers	Countries With Make/Buy Efforts	
China	India	Argentina
France	Japan	Egypt
United Kingdom	North Korea	Iran
United States	Taiwan	Israel
USSR	South Korea	Iraq
	Pakistan	Libya
	Brazil	Syria

Once an enrichment capability has been obtained, a developing country could proceed with actual weapon system development. A design incorporating an implosion device would be the most desirable, allowing development of a fusion yield enhancer (hydrogen bomb). HE material such as HMX for core compression is readily available, but high-speed krytron switches and capacitors are difficult to acquire from Western countries. In addition, sufficient quantities of beryllium—essential to minimize core size—may not be available to a developing country. Also difficult to obtain would be sufficient quantities of ^{210}Po—the half-life is only 138 days—for use as a neutron initiator. Metallurgical skills needed for final weapon fabrication may also be lacking in some countries. In addition, the warhead components must be designed or modified to withstand great stresses during ballistic missile flight.

Despite these obstacles, a determined nation with sufficient funding could acquire or develop all the components and materials needed to build a nuclear warhead. The Iraqis made purchases from hundreds of companies scattered over a dozen countries, and they masterfully exploited the "dual-use" loopholes in most countries' export regulations. Ultimately, Iraq decided to purchase the machines and tools necessary to produce their own nuclear weapon-grade components. *[Ref. 94]*

The successful production, purchase, or theft of a nuclear weapon by a developing country could fundamentally alter world events. If, for example, Iraq had been known to possess several nuclear devices when it invaded Kuwait, U.N. coalition forces might have responded differently, knowing that the possibility (however remote) of a nuclear warhead successfully detonating over an Israeli or Saudi city was real.

Biological Warhead Technology

Ever since the Tartars catapulted the bodies of bubonic plague victims over the walls to break sieges, biological warfare has been considered a viable military option. Biological weapons appear to provide a great equalizer for countries that do not have nuclear weapons or that view their adversaries as too numerous or technically superior to engage in a conventional confrontation.

There is a strong international stand against biological warfare. The development, production, and stockpiling of biological and toxin weapons were banned under the 1972 Biological Weapons Convention, to which 110 countries are signatories. However, the ban permits research to develop defenses against biological agents.

Many countries, including the United States, have conducted extensive research to assess antidotes and to test the performance of protective garments against these agents. A number of countries have experienced fatal accidents while developing these defensive measures.

Biological warfare involves the deployment of bacteria, viruses, rickettsiae, fungi, protozoa, and toxins from organic matter to produce death or disease in humans, animals, or plants. Biological agents are generally divided according to their effects. Some are known to cause death; others are considered only incapacitating to healthy adults but could prove lethal to the young, aged, or people in poor health. Livestock is particularly susceptible to a wide range of agents, many of which are specific to cattle, pigs, sheep, goats, horses, or other animals (i.e., they will kill only these species). The diseases can be passed to humans in meat products, and wholesale slaughter is often the only means of containing the disease.

Iraq has demonstrated how easy it is to manufacture biological agents. In 1974, Iraq signed a contract with Institute Merieux in Paris to set up a bacteriological laboratory to produce vaccines to improve animal and agricultural production. This plant was eventually built and set

Incubation Period of Biological Agents

Biological Agent	Incubation Period
Death	
Plagues	>1 week
Whitmore's disease	>1 week
Equine encephalomyelitis virus	>2 weeks
Botulism	>3 weeks
Nocardia asteroides fungus	>4 weeks
Fever/Rashes/Pain	
Influenza	>1 week
Shigella dysenteriae	>1 week
Rabbit or deer fever	>1 week
Diphtheria	>1 week
Yellow fever	>1 week
Rickettsiae	>2 weeks
Dengue fever	>2 weeks
Smallpox	>3 weeks
Typhoid fevers	>3 weeks
Paratyphoid fevers	>3 weeks
Undulant fever	>4 weeks
Hepatitis A	>4 weeks
Hepatitis B	>4 weeks
Turberculosis	>4 weeks
Nine-mile and Q fevers	>4 weeks
Swelling/Respiratory Infections	
Anthrax	>1 week
Gladers	>1 week
Psittacosis	>2 weeks
Coccidiodes immitis fungi	>3 weeks
Histoplasma capsulatum fungi	>3 weeks
Nausea/Convulsions	
Staphylococcus toxin	Minutes to hours
Samonella	Minutes to hours
Cholera	>1 week
Encephalitis	>2 weeks

the stage for producing anthrax and other biological agents. Iraq also has a confirmed biological warfare research facility at Salman Pak. The Iraqis have purchased a great deal of equipment capable of developing agents for cholera, anthrax, typhoid, and various microtoxins. However, engineering these agents into biological weapons is much more dangerous than it is for chemical weapons.

The Kurdish Democratic Party has accused Iraq of directing biological attacks against Kurdish villages. This charge is difficult to prove, however, since all of the species reported occur naturally in the Kurdish-occupied areas.

From all indications, several other countries in the Middle East are working on biological weapons:

- The Iranians are believed to have a research facility for biological weapons in Damghan. The chief of staff of the Iranian armed forces once stated that biological weapons are an appropriate defense since there is no nuclear parity for them.
- Syria is reported to have a biological warfare program that may have been started with help from North Korea, whose own program is well known. Waterborne agents are the main concern of Israel, which shares the Sea of Galilee with Syria.
- Libya has a biological warfare facility at Sebha, in Tezzan province. The research there is reported to have been supported by the Soviets.

A 1970 World Health Organization report concluded that biological warfare was impractical due to the high risk of backfire and the restrictions on occupying the contaminated territory for what could be a very long time. As a terror weapon, however, biological agents pose a great threat. Moreover, biological agents can be manufactured simply and clandestinely in a small laboratory.

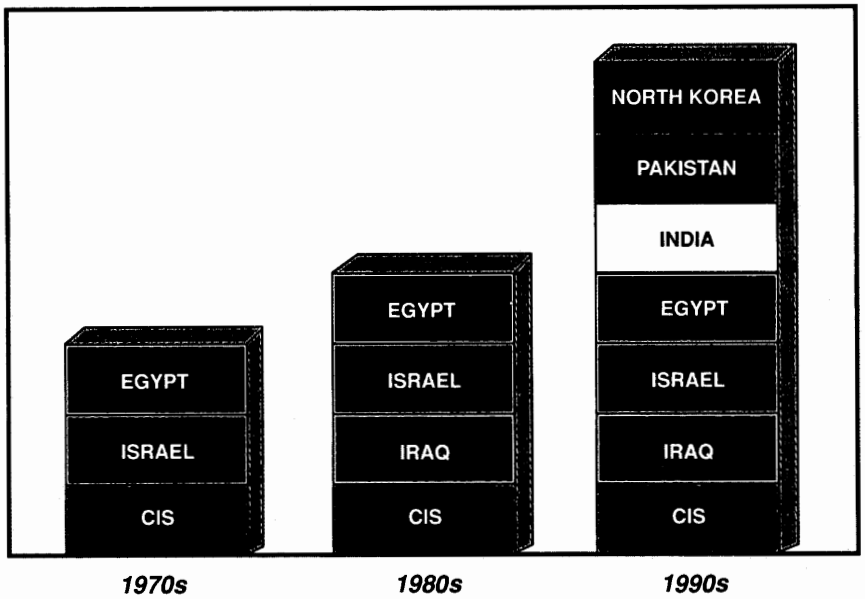
Chemical Warhead Technology

Many elderly Americans and Europeans vividly remember the mustard gas survivors of World War I, who were often impaired with severely diminished lung capacity. As a result of those terrible experiences and the revulsion felt around the world, chemical weapons disappeared from the field of combat in World War II and the conflicts in Korea and Vietnam.

Since the 1970s, however, the number of countries possessing chemical weapons has increased dramatically. And despite continuing worldwide censure, there have been several incidents in which chemical weapons were reportedly used. Some of these incidents, like the infamous "yellow rain" allegedly dispersed by the Soviets in Afghanistan, have never been entirely confirmed. Others,

Chemical Warhead Growth Trends

Chemical warhead technology is proliferating: over twice the number of countries in the 1990s vs. the 1970s.



Toxicity of Typical Chemical Agents

Chemical Agent	Toxicity
Nonpersistent	
Diphenyl chloroarsine (DA)	Low
Diphenyl cyanoarsine (DC)	Low
Adamiste	Low
Tabun (GA)	Low
Sarin (GB)	Low-medium
Hydrogen cyanide (AC)	Low-medium
Medium Persistence	
Psychochemical (BZ)	Low
Tear gas (CS)	Low
Soman (GD)	High-medium
Highly Persistent	
Sulfur mustard (H)	Low
Phosgen oxime (CX)	Low
Nitrogen mustard (HN-3)	Low-medium
GF	High-medium
VX	High

such as the civil conflict in which the Iraqis dropped chemical agents on Kurdish villages, are virtually undisputed, and they provide chilling evidence as to the horrible effects of chemical warfare. Chemical weapons release toxic gases or liquids that attack the body's nerves or blood; that produce surface effects like tears, blistering, or vomiting; or that cause hallucinatory incidents. Chemical agents can be virulent and can persist long after dispersal. Nerve gases are particularly toxic. Halogen-based gases, which produce blistering, may be somewhat less toxic, but their persistence makes escape difficult and gas masks vital. For chemical agents, the problem is one of toxicity and persistence. Nerve gases provide the most immediate effect, and they are also among the most persistent.

Iraq has also demonstrated how easy it is to manufacture chemical agents. In 1983, a German chemical company completed a pesticide plant for Iraq. The products of this plant were sent to another plant in Samarra where tabun and sarin were manufactured. This plant reportedly had production lines furnished by German, French, and Soviet suppliers. Also in 1983, Iraq reportedly purchased theodiglycol from a Belgian subsidiary

of Phillips Petroleum, using KBS, a Dutch trading company, as a middleman. Theodiglycol, when mixed with hydrochloric acid, produces mustard gas. The early chemical weapons used by Iraq against the Kurds were mixtures of mustard gas, yellow rain, and tabun. Eventually, a mixture of hydrogen cyanide, mustard gas, sarin, and tabun—packaged in Spanish bomb cases furnished by EXPAL—was found to be more effective.

Fourteen countries have been accused of developing chemical weapons, and nearly all of them have admitted to having a defensive research program. In Iraq, the Kurdish Democratic Party has claimed that there are chemical warhead laboratories at Akashat, Badoush, Al Fallujah, and Samarra. A suspected chemical warhead facility has also been identified at Al Damghan, Iran. In Libya, chemical warhead facilities have been reported at Rabta, Sebha, and Tripoli. The Soviets may have assisted Libya in the operation of these facilities, at least before the massive political and social changes that occurred in the Soviet Union in 1991.

Among developing nations, only India, Egypt, Iraq, Israel, and Pakistan are known to have chemical weapons. However, any country with missiles carrying payloads of 500 to 1,000 kg could also produce a viable chemical warhead with a modest effort.

Chemical-Warhead-Capable Ballistic Missiles

Developing Country	Ballistic Missile
Afghanistan	Scud B
Argentina	Alacran
Brazil	SS–300
China	M–9/11
Egypt	Scud B
India	Prithvi, Agni
Iran	Scud B
Iraq	Al Hussein
Israel	Jericho 2
Libya	Al Fatah
Pakistan	Hatf

SIPA PRESS

Kurdish Victims of Iraqi CW Attack

THE ROLE OF ARMS AND WARHEAD TECHNOLOGY CONTROLS

With possibly five developing countries possessing nuclear weapons and about a dozen possessing biological or chemical weapons, and with several others suspected of actively developing NBC weapons, the world has focused increased attention on controlling the spread of these weapons of mass destruction. Various multilateral arms and technology control regimes have been created to check the horizontal proliferation of these technologies. Once a state has acquired weapons of mass destruction, however, efforts aimed at blocking their vertical proliferation have been ineffectual and virtually unverifiable.

Formal Treaties

As described in the previous chapter, several multilateral arms control regimes exist that seek to prohibit the acquisition and development of nuclear weapons. The 1963 Limited Test Ban Treaty prohibits all testing (or detonation for any other purpose) of a nuclear device in the atmosphere, in outer space, or under water. Most countries have signed it; notable exceptions are China, France, and North Korea.

The 1968 Non-Proliferation Treaty (NPT) aims to prevent the spread of nuclear weapons and to provide assurance (through agreement to international nuclear safeguards and related International Atomic Energy Agency (IAEA) inspections) that peaceful nuclear activities of non-nuclear weapon states will not be diverted to developing such weapons. Over 130 countries have signed the treaty, but again there are some notable exceptions, including China, India, Pakistan, and Israel; others (such as North Korea) have signed the NPT but not the IAEA Safeguards Agreement, so they do not permit inspections of their nuclear facilities to determine whether efforts and resources are being diverted to develop nuclear weapons.

Argentina and Brazil, although not signatories to the NPT, are parties to the 1967 Treaty for the Prohibition of Nuclear Weapons in Latin America. This treaty establishes a Latin American nuclear weapons-free zone (prohibiting acquisition, possession, storage, or deployment). Virtually all Latin American states except Cuba have signed this accord; none of the signatories are known to have violated the treaty.

Other nuclear proliferation control treaties include the 1967 Outer Space Treaty and the 1971 Seabed Arms Control Treaty. These agreements prohibit the placement of nuclear weapons or other weapons of mass destruction in outer space and on the seabed and ocean floor, respectively.

Two formal treaties and one ongoing negotiation seek to prevent proliferation of biological and chemical weapons. The 1972 Biological Weapons Convention (signed by most countries) prohibits the acquisition, development, and stockpiling of biological and toxin weapons and requires the destruction of any such existing materials. This agreement builds on the 1925 Geneva Protocol that prohibits the use of poisonous gases and bacteriological weapons in war. The Chemical Weapons Convention (CWC) is an ongoing negotiation of the United Nations Conference on Disarmament (CD) that seeks to achieve a treaty banning chemical weapons. Thirty-nine states are participating in the negotiations, with 21 others acting as "observers."

Although these formal treaties might have slowed the pace of NBC weapon proliferation, they have not succeeded in preventing it, especially if a state is determined to commit the resources necessary to acquire such weapons. Not all of the countries that aspire to possess these weapons have signed the aforementioned treaties, leaving them free to acquire NBC weapons and subsequently to transfer the acquired technologies to other states. Even agreeing to sign these treaties is no guarantee that a state will abide by their provisions. A prime example is Iraq, which was developing (if not in possession of) nuclear and biological weapons prior to the Persian Gulf war despite being a signatory to the Geneva Protocol, the Biological Weapons Convention, and the NPT; and which possessed enormous stores of chemical weapons despite being an observer in the CWC. (In response to revelations about Iraqi weapons programs, the IAEA announced plans to tighten safeguards imposed on all NPT signatories in an attempt to ensure that their peaceful nuclear programs are not diverted to military purposes.)

The effective implementation of these multilateral agreements to date is hindered by a lack of strict verification procedures (an issue in the CWC negotiations) and any agreed sanctions to be imposed on signatory states that have violated an agreement.

Informal Approaches

Informal arms and technology control measures also have been implemented as corollaries to formal treaties. Informal technology control regimes include:

- The Australia Group, consisting of 20 states under the leadership of Australia that have agreed to restrict (if not ban) the sale of chemical weapons precursors.
- The London Nuclear Suppliers Group, a cartel of nuclear exporting countries that seeks to place curbs on "dual use" items.
- The Zangger Committee (also known as the Nuclear Exporters Committee), a group of NPT signatories that have agreed to prohibit the export of certain items to any nonnuclear state without its acceptance of IAEA safeguards and a pledge of "no explosive use."

CoCom, described in Chapter Five, also plays a role controlling warhead technology.

The Group of Five (United States, Soviet Union, United Kingdom, France, and China) committed themselves in 1991 to the objective of eliminating all weapons of mass destruction from the Middle East. This came in the wake of the cease-fire that ended the Persian Gulf war. Under the terms of that agreement, Iraq is compelled to make full disclosure of its NBC weapon and ballistic missile (of a range greater than 150 km with no payload) holdings and production facilities; once verified by inspection, the weapons and facilities will be destroyed. Iraq is further prohibited from developing or acquiring such missiles indefinitely.

There is no known case of any of the five announced nuclear powers transferring NBC weapons to another country. However, there is some evidence that private firms (if not the states themselves) have assisted some developing nations in their nuclear and chemical weapon development programs. This assistance has been provided despite the existence of national export controls and international agreements (both formal and informal) to restrict the flow of technologies and supplies that could be used in the development of weapons of mass destruction.

The record on control of vertical proliferation is dismal. Once a state has gained a chemical or nuclear weapon capability, there is little precedent for treaty-required destruction of the warheads. This is evident from the record of the U.S. and USSR bilateral arms treaties. The two superpowers agreed in 1990 to destroy half of their chemical weapon stockpiles by the end of the decade; however, Soviet adherence to this schedule is in doubt, given the collapse of its central government. The United States and the Soviet Union recently announced unilateral initiatives to withdraw and destroy most of their tactical nuclear weapons—the first time that they have agreed to destroy nuclear warheads instead of delivery vehicles.

Chapter Seven

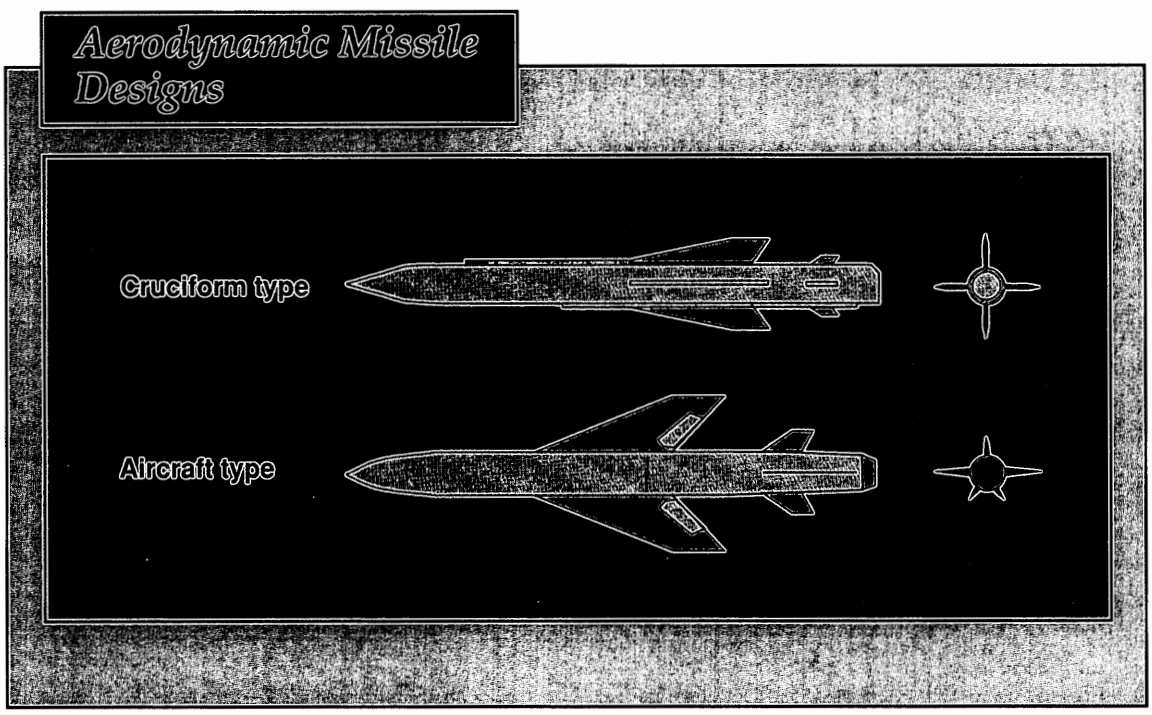
Aerodynamic Missiles

An analysis of offensive missiles must take into account the existence of unmanned aerodynamic systems, which are becoming increasingly common throughout the world. These unmanned weapon delivery vehicles sustain flight for most of their trajectory by the force of aerodynamic lift.

The most common aerodynamic missile is the cruise missile. The technologies required to build advanced cruise missiles are within the reach of a considerable number of nations, and the existence of cruise missiles—especially for antiship missions—has a long history. However, it is useful to consider the broader category of aerodynamic missiles as the operative concept. Aerodynamic missiles are capable of delivering payloads to ranges out to 3,000 km or more. Technically, some of these missiles are neither cruise missiles nor ballistic missiles.

The first aerodynamic missiles were based on manned aircraft or drone designs that were scaled up or down for the range and payload weight desired. These two-wing and three-surface-tail designs used standard liquid-fueled aircraft engines and autopilots. In time, more sophisticated guidance systems were used, including command updates and then terminal guidance systems incorporating passive or active radar and passive infrared (IR) seekers. Inertial systems were eventually used in place of the autopilot with the same terminal options except for the addition of target comparison through TV or IR imaging. Liquid fuels were replaced with solid propellants to improve maintainability. When greater ranges were needed, turbojets and turbofans were added; when higher specific energies were required for distance or speed, ramjets were employed. Four-wing/four-tail cruciform designs using solid propellants, turbojets, and ramjets were introduced

Note: The material in this chapter was compiled from three primary sources: *Jane's Air-Launched Weapons,* D. Lennox and A. Rees, eds., 1990 [Ref. 103]; *Jane's Naval Weapon Systems,* E. Hooton, ed., 1990 [Ref. 76]; and N. Friedman, *The Naval Institute Guide to World Naval Weapons Systems 1991/92,* 1991 [Ref. 80].



in the 1960s. These missiles initially incorporated passive radar alone or autopilots with passive radar, but these were soon replaced with inertial guidance systems having a full array of available terminal homing systems.

Most aerodynamic missiles were acquired initially to attack ships and airplanes or to defend coastal areas. Some of these missiles were subsequently adapted to attack targets on land. Aerodynamic missiles can be launched from aircraft, from the ground, from ships, or from submarines. They form an often neglected, but very real, dimension of the emerging offensive missile threat.

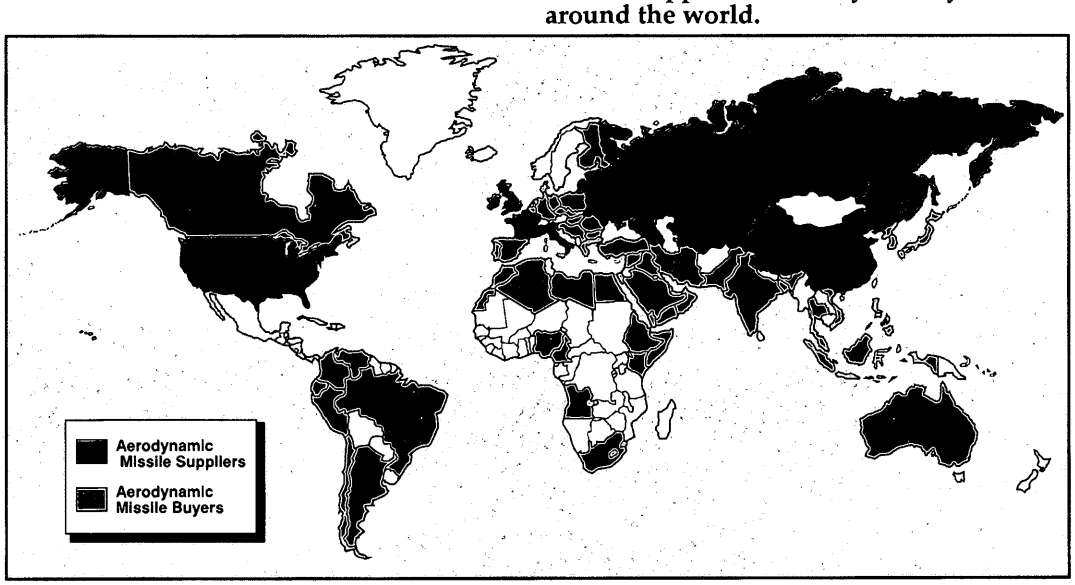
To date, most proliferated cruise missiles have been relatively short-range weapon delivery vehicles. Long-range cruise missiles, like the Tomahawk land-attack missiles used to great effect in the Gulf war, require sophisticated guidance and fairly complicated support infrastructures to map terrain or in other ways assist in targeting the missiles. However, as more accurate guidance sets become available worldwide (e.g., through commercial applications of the Global Positioning System and other technologies), the range of cruise missiles also is likely to increase.

Aerodynamic missiles have been included in this publication for six reasons:

- They are available from many suppliers, which makes them easy to obtain, and they tend to be quite easy to deploy and use.
- They have been sold throughout the world to many countries, large and small, making them a constant threat to U.S. installations and allies.
- The purchase of aerodynamic missiles and their technology indicates an intent on the part of a country to enter into the world of modern warfare.
- Cruise missiles and their technology provide a first step that supplies some of the technologies that might lead to future ballistic missile programs.
- As the range of cruise missiles increases, their missions and warheads become very similar to those of longer range ballistic missiles.
- Defensive systems may have or can be made to have significant capabilities against both ballistic and cruise missile threats.

Aerodynamic Missile Suppliers and Buyers

There are seven principal aerodynamic missile suppliers and sixty-six buyers around the world.



Aerodynamic Missile Development Range Categories (km)*

Country	30+	60+	120+	240+
Coastal Defense and Ship-Launched				
Brazil		SM−70 Barracuda		
China	HY−1 (CSS−N−1) (C−101)^{R} F−1, −2^{S}, −7 YJ−1 (C−801)^{S}	HY−2 (C−201) HY−3 (C−301)^{R} YJ−2 (C−802)^{T}	HY−4 (C−201W)^{T}	
France	MM 38 Exocet^{S}	MM 40 Exocet^{S}	ANS^{R}	
Iraq		FAW 70	FAW 150, 200	
Israel	Gabriel Mk 2, 3^{S}		Gabriel Mk 4 LR^{T}	
Italy		Otomat Mk 1^{T}	Otomat Mk 2^{T}	
Japan	SMM−1^{T}		SMM−2^{T}	
N. Korea	HY−1	HY−2		
Norway	Penguin Mk 2^{S}			
S. Africa	Skorpioen^{S}			
Sweden	RBO4^{S}	RBS−15^{T}		
Taiwan	Hsiung Feng 1^{S}	Hsiung Feng 2^{T}		
U.K.		Sea Eagle^{T}		
USSR	SS−N−2A SS−N−14 SS−N−15	SS−N−2C SS−N−7^{S} SS−N−9^{S} SS−N−22^{S} SSC−1	SS−N−16	SS−N−3^{T} SS−N−19^{T} SSC−1b^{T}
U.S.			Harpoon A−C^{T}	Harpoon D^{T} Tomahawk B^{T}
Air-Launched				
China	C−101^{R} YJ−1 (C−801)^{S}	C−601 YJ−2 (C−802)^{T}	HY−4^{T}	
France	AM 39 Exocet^{S} AS−37 Martel AR^{S}	Armat^{S}	Apache^{T}	ASMP^{R}
Germany	AS−34 Kormoran 1, 2^{S}			
Iraq	Ababeel	Nisan 28		
Israel	Gabriel Mk 3 AS^{S}	AGM−142 Popeye^{S}	Gabriel Mk 4 LR^{T}	
Italy		Mk 2B Marte^{S}		
Japan	ASM−1 (Type 80)		ASM−2 (Type 83)^{T}	
Norway	Penguin Mk 2, 3^{S}			
Sweden		RBS−15F^{T}		
Taiwan		Hsiung Feng 2^{T}		
U.K.	ALARM^{S}	Sea Eagle^{T}		
USSR	AS−12	AS−2^{T}, −9	AS−4, −5, −11^{S}, −16	AS−6B^{S}
U.S.	Standard^{S}	Tacit Rainbow^{T}	SRAM^{S} Harpoon A^{T}	SRAM^{S}

*Both the United States and the USSR have developed additional missiles with ranges out to over 4,000 km.

S – Solid; T – Turbojet/Turbofan; R – Ramjet

Aerodynamic missiles have been developed throughout the world. Sixteen countries produce aerodynamic missiles with ranges equal to or greater than 30 km, and 66 additional countries have purchased them from one or more of these producers. Eleven of the 16 countries that build aerodynamic missiles also build ballistic missiles. The emphasis later in this chapter is on that subset of missiles which have actually been reported as sold.

PATTERNS OF AERODYNAMIC MISSILE TECHNOLOGY TRANSFER

The technology transfer patterns for aerodynamic missiles are even more interesting than those for ballistic missiles, largely because the proliferation of aerodynamic systems is greater and there is more interaction between the developing countries. Aerodynamic missiles are manufactured in two basic configurations: the airplane-like design with two wings and three tail surfaces, and the more advanced configuration with four wings and a cruciform (four-surface) tail. The Soviet Styx was essentially the father of most of the aircraft configuration designs. The Styx B was the model for the Chinese HY–1 and a North Korean HY–1 design; the Styx C became the Chinese HY–2 Silkworm and the North Korean HY–2. Each transfer took about 10 years—about one-half to two-thirds the time typically required for ballistic missiles. In turn, the Chinese and North Korean Silkworms became the Iraqi FAW 70. The Soviet Styx C was also converted into an air-launched version called the AS–9 Kyle, which in turn evolved into the Chinese C–601 and the Iraqi Nisan 28.

The USSR also developed solid-propellant versions for better maintainability and turbojet/turbofan versions for greater range capability. The Chinese followed suit, again with a lag of about 10 years. The Soviets began with autopilots and later added radio command capability. They then incorporated a terminal guidance system, first using an active radar and then substituting a passive IR homing sensor. Later they switched to turbojets to produce longer ranges and to an inertial-based midcourse system, first with active radar terminal guidance and eventually with terrain-matching terminal guidance. The Chinese imitated the change from liquid to solid propellant and from solid propellant to turbojets, but retained the autopilot. This gave them a much smaller range improvement—the Chinese missiles appear limited to ranges below 150 km. For the airplane configuration, all four countries developing these designs had interactive technology transfer.

France, the United Kingdom, Germany, and Italy have a complex interactive relationship in their aerodynamic missile development programs. The French AS–37 with a passive radar homing device was developed cooperatively with the United Kingdom, which fielded a shorter range TV-guided version. The French design evolved into the Exocet and Armat, the British version became the Sea Eagle, and the Germans and Italians produced the Kormoron and Otomat, respectively. All these systems used inertial midcourse and active radar guidance. The Italians also developed a passive radar-only Marte Mk 2B to replace the French Martel AS–37.

The Exocet and Otomat were widely sold throughout the world. China and Japan apparently reverse-engineered the Exocet into the YJ–1 and ASM–1, respectively, both in the mid 1980s; the YJ–1 is for sale. Norway and Sweden have also cooperated in their unusual canard design (nose-located control fins), one version of which has been sold to Turkey.

Taiwan has reverse-engineered the U.S. Harpoon into the Hsiung Feng 2 (HF–2) and reportedly offered the missile for sale. In addition, Israel apparently sold the Gabriel Mk 2 production lines to South Africa and Taiwan when the missile was being phased out for the Mk 3. South Africa and Taiwan produce Gabriel Mk 2s under the respective names of Skorpioen and Hsiung Feng 1 (HF–1).

The essential problem is that much of the technology for aerodynamic missiles is relatively simple and has been proliferating for decades. The technology flow for aerodynamic missiles incorporating a cruciform tail is a two-sided transfer: (1) old technology is being franchised out or reverse-engineered by countries with the ability to proliferate and improve it, and (2) the transfer between the major European and U.S. suppliers is becoming intensely competitive. For the supplier

countries, missile technology sales buy oil, so sales are as vigorous as can be managed within the context of the political discussion on nonproliferation. This leads to the overall problem of technology transfer.

TRADITIONAL SUPPLIERS

For many years, the Soviet Union, United States, China, France, Italy, United Kingdom, and Israel have been the world's major suppliers of cruise missiles. All seven countries have provided aerodynamic missiles to their friends and allies.

USSR

The USSR exported cruise missiles throughout the Warsaw Pact, Middle East, and Far East. Many countries have copied Soviet designs to produce indigenous versions.

Styx and Derivatives

The USSR began development of the Styx family of antiship missiles in the mid 1950s. The general configuration of a Styx missile is that of a small aircraft with a delta platform wing. The SS–N–2A, which became operational in 1959, employs a liquid-propellant motor with a solid-propellant booster that is jettisoned after takeoff. The missile is designed to carry a 400-kg payload to a range of 45 km. *[Ref. 32]*

The Styx is 5.8 m long and 0.76 m in diameter, and has a launch weight of 2,300 kg. The SS–N–2B is identical to the –2A except that it incorporates folded wings and an updated guidance system. The SS–N–2C is slightly larger and carries a 500-kg warhead to a range of 80 km. The SS–N–3, a coastal defense version of the –2C, can also deliver a 500-kg warhead to a range of 80 km. The A version of this delta-winged airbreathing missile uses an I-band radar seeker with prelaunch selection of one of six available frequencies. The SS–N–3 is typically launched from one of four sealed containers inclined at a fixed angle. The missile climbs to a preset altitude and then proceeds through a shallow angle dive or a glide angle terminal phase. In the B version, the wings unfold just after launch, and a passive IR seeker replaces the J-band radar. The C version uses either the IR or the radar seeker with a command guidance capability in midcourse and adds an improved altimeter to allow the missile to fly a sea-skimming approach in the terminal phase. The D version increases the missile range to 100 km and adds a V-band radar seeker. *[Ref. 32]*

USSR Missile Sales

Missile	Range (km)	IOC	Customers
Coastal Defense and Ship-Launched			
SS–N–2 (Styx)	35/80	1959/1962	Algeria, Angola, Bulgaria, China, Cuba, East Germany, Egypt, Ethiopia, Finland, India, Iraq, Libya, North Korea, Poland, Romania, Somalia, Syria, Tunisia, Vietnam, Yemen, Yugoslavia
SS–N–7 (Starbright)	100	1971	India
SS–N–3b (Sepal)	450	1963	Syria
Air-Launched			
AS–9 (Kyle)	90	1971	Bulgaria, Czechoslovakia, East Germany, Hungary, Iraq, Libya, Poland, Romania
AS–5 (Kelt)	180	1966	Egypt

Styx missiles typically are carried on Osa-class missile boats. The boats and missiles have been exported to 21 countries. These missiles have been used effectively in naval combat and coastal defense over the past three decades. An Egyptian Styx sank an Israeli destroyer in the 1967 Middle East War. India destroyed a Pakistani mine sweeper and destroyer in 1971. Most recently, Iraq sank several Iranian ships during the protracted war between those two countries during the 1980s.

Several countries have built Styx missiles under license arrangements with the USSR. China, North Korea, and Iraq have modified the basic Styx design. The Hai-Ying (HY) family of Chinese antiship missiles includes the HY–1, the HY–2, and the HY–4 upgrade of Silkworm. *[Ref. 32]*

The Iraqis built the FAW family of coastal defense missiles, apparently following the Soviet Styx design. FAW missiles have folding delta wings and a triple tail. The FAW 70, 150, and 200, all of which became operational in 1989, can deliver a 500-kg warhead to the ranges indicated by the missile designators. *[Ref. 32]*

Starbright

The SS–N–7 (Starbright) was originally a submarine-launched antiship cruise missile. The missile is 7.0 m long and 0.5 m in diameter, and has a launch weight of 2,800 kg and a payload of 500 kg; the warhead may be conventional or nuclear. Guidance is provided by an autopilot with an active radar. The missile has a range of 100 km. *[Ref. 32]*

The Starbright is being phased out for the SS–N–9 (Siren). One "Charlie 1" class submarine that was sold to India in 1988 was reported to have eight Starbright missiles as part of its weapons complement.

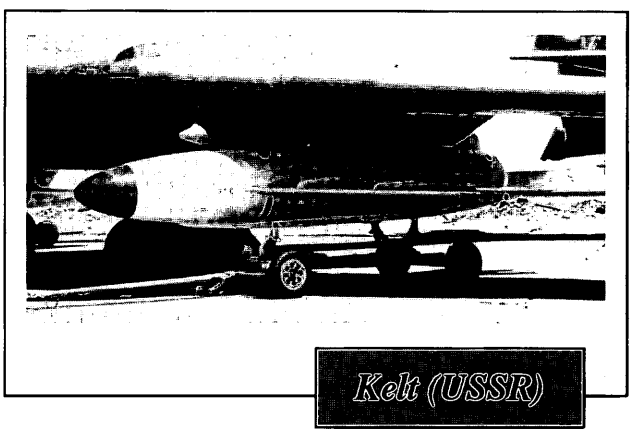
Sepal

The Sepal cruise missile is a coastal defense version of the SS–N–2 (Styx). It has a similar command and seeker capability but a considerably longer range than the Styx. The Sepal is 10.2 m long and 1.0 m in diameter. It has a launch weight of 5,300 kg and carries a single warhead of 1,000 kg, either conventional or nuclear. The missile has a range of 450 km. *[Ref. 32]*

The Sepal has been exported only to Syria, which is reported to operate a single battalion (15–18 launch vehicles).

Kelt

The AS–5 (Kelt) is an air-launched antiship missile that was developed in the early 1960s. It is thought to have entered service in 1966. The general configuration of the missile is that of a small aircraft; it has swept wings at midbody with tailplanes and fins aft. The AS–5 is 8.59 m long and has a body diameter of 0.9 m and a wingspan of 4.8 m. The missile weighs 3,000 kg at launch and carries a warhead of about 1,000 kg. Its range is 180 km. Midcourse guidance is inertial with a J-band radar for terminal homing. The missile has two different attack modes, a sea-skimming trajectory and a high-altitude trajectory. *[Ref. 103]*



JANE'S INFORMATION GROUP

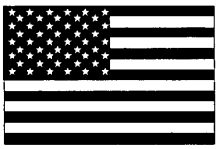
The Kelt has been sold to the Egyptian air force. About 25 were launched against Israeli forces in the 1973 war, with five reported hits. There are no other known exports.

Kyle

The AS–9 (Kyle) is a medium-range, antiradiation, air-to-surface missile. It was developed in the late 1960s and is believed to have entered service in the early 1970s. The AS–9 was designed to attack ground-based and shipborne radars. The missile is 6.0 m long and has a body diameter of 0.5 m and a wingspan of 2.0 m. It has two delta wings at midbody with clipped-tip delta vertical fins and horizontal tail planes. The missile is estimated to weigh about 750 kg and is reported to have an HE warhead of around 200 kg. It flies a high-altitude trajectory with a steep dive terminal phase. The range of the missile is 90 km. *[Ref. 103]*

The Kyle has been widely exported to Warsaw Pact countries as well as to Iraq and Libya. The Iraqis call their version the Nisan 28. *[Refs. 32, 63]*

United States



The United States has exported cruise missiles to many areas of the world, including NATO allies, the Middle East, the Far East, and South America—23 countries in all.

U.S. Missile Sales

Missile	Range (km)	IOC	Customers
Harpoon	130	1977	Australia, Brunei, Canada, Denmark, Egypt, Germany, Greece, Indonesia, Iran, Israel, Japan, South Korea, Kuwait, Netherlands, Pakistan, Portugal, Saudi Arabia, Singapore, Spain, Thailand, Turkey, United Kingdom, Venezuela

Harpoon

Harpoon is a turbofan-propelled antiship cruise missile with three variants—air-launched, ship-launched, and submarine-launched. This radar-guided missile carries only a conventional HE warhead designed for blast penetration. Harpoon flies in a sea-skimming mode using a radar altimeter and homes on the target with an active J-band, frequency-agile seeker that scans in two axes. The Block B version operates entirely in the sea-skimming mode; Block M adds a climb-and-dive final approach; Block 1C uses an initial high-altitude mode to avoid friendly ships or land spits and then drops down to the sea-skimming mode. Block 1D is expected to double the range and provide a retargeting capability

Harpoon is 3.85 or 4.5 m long, depending on the variant, with a body diameter of 0.34 m. The launch weight is 522 or 630 kg, and the missile carries a single warhead weighing 220 kg. The range is 100–120 km. The Harpoon has four clipped-tip triangular wings at midbody and four smaller clipped-tip triangular moving control fins at the rear. *[Ref. 32]*

JANE'S INFORMATION GROUP

Harpoon (United States)

The United States used Harpoons in the attack on Libya in 1986. Iran might have used some of the Harpoons that were acquired during the Shah's regime in its war with Iraq.

China

Chinese cruise missile development has been based primarily on the Soviet Styx provided to them in the late 1950s. During the late 1960s, the Chinese built their own version, which they called the Hai Ying–1 (HY–1). All exported missiles except for the YJ–1 seem to trace their heritage to this family of missiles.

The HY Family

The HY–1 and HY–2 (Silkworm) are the Chinese versions of the Soviet Styx. They are short-range, ground- and ship-launched, liquid-propelled, single-warhead, surface-to-surface cruise missiles. The general configuration of the missiles is similar to the Styx. The HY–1 and HY–2 have a body length of 5.8 m and 6.55 m, respectively; the body diameters are nearly the same, about 0.76 m. The launch weight is 2,300 kg for the HY–1 and 2,500 kg for the HY–2, and the

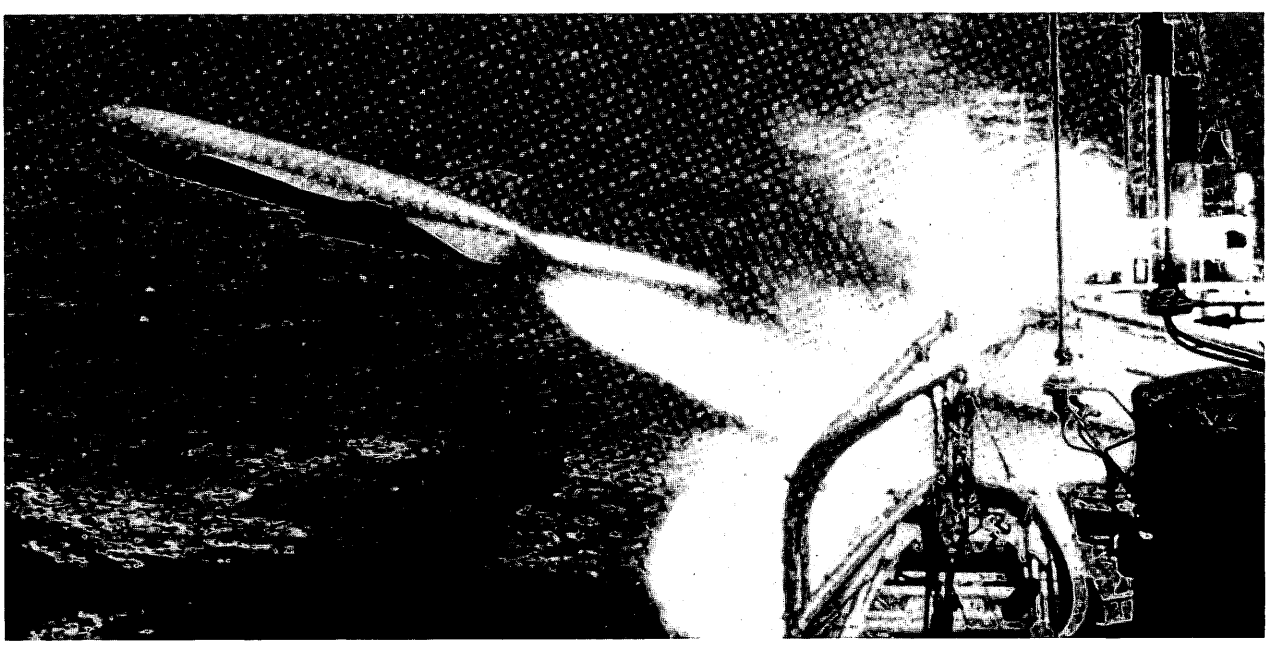
warheads weigh 400 kg and 500 kg, respectively. Both missiles use an autopilot and an active radar for guidance, and the HY–2 includes an IR option. The range of the HY–1 is 40 km, while that of the HY–2 is 80 km. *[Ref. 32]*

Chinese Missile Sales

Missile	Range (km)	IOC	Customers
Surface-Launched			
HY–1	40	1970	Bangladesh, Egypt, North Korea, Pakistan
HY–2	80	1978	Iran, Iraq, North Korea
FL–1	40	1980	Bangladesh, Pakistan, Thailand, Egypt
YJ–1	40	1984	Thailand
HY–4	150	1991	Iran
Air-Launched			
C–601	95	1980	Iran

The Silkworm has been sold to six countries, and a production line for both the HY–1 and the HY–2 has reportedly been set up in North Korea. The HY–2 was reported to have been used by both Iran and Iraq during their war between 1980 and 1988. *[Ref. 86]*

The HY–4 is a long-range, radar-guided cruise missile. It is believed to be an enlarged version of the HY–2. The HY–4 incorporates a turbojet engine, replacing the liquid-propellant motors of the HY–2. The HY–4 has been developed primarily as an antiship coastal defense system capable of launch from the ground or from ships, but an air-launched version has been developed as well. The missile has two clipped-tip delta wings with ailerons at midlength, triform tail fins at the rear, and the turbofan engine intake under the center of the body. The missile is 7.36 m long with a body diameter of 0.76 m and a wingspan of 2.8 m. The air-launched version, which lacks the solid-propellant boost motor used in the ground- and ship-launched versions, weighs 1,740 kg. An autopilot is used for midcourse guidance, and there is an active J-band radar terminal seeker. The missile cruises at Mach 0.8 and delivers a 500-kg warhead to a range of 150 km. The HY–4 has been sold to Iran. *[Ref. 32]*



JANE'S INFORMATION GROUP

Silkworm (China)

The C–601 is a variant of the HY–2 that is nearly identical in dimensions to the HY–4 but retains the liquid propellant system of the former. The maximum range has been reduced to 95 km. It, too, has been sold to Iran. *[Ref. 32]*

The FL Family

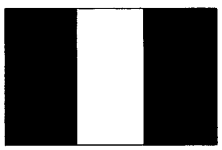
The FL family of Chinese missiles also appears to have been developed from the baseline Styx design. The Fei-Long (Flying Dragon) 1 vehicle is similar in size and shape to the HY–2. It cruises on autopilot at an altitude of 30 m and then drops to 8 m in the terminal phase, homing in with a J-band monopulse radar seeker. The liquid-propellant missile is 6.42 m long with a body diameter of 0.76 m and a wingspan of 2.4 m. The missile weighs 2,000 kg without the solid-boost motor. It cruises at Mach 0.9 and delivers a 500-kg HE warhead to ranges out to 40 km. The FL series all use the same HY–2 missile containers and fire control systems. The FL–1 has been sold to Bangladesh, Pakistan, Thailand, and Egypt. *[Ref. 32]*

The Chinese have improved guidance and other features in the FL–2 through FL–6. The FL–7, a supersonic version of the FL–2, has a claimed maximum speed of Mach 1.4. Although probably still under development, the FL–7 reportedly can deliver a 365-kg warhead to a range of 30 km. The Chinese also have an air-launched version of the basic Styx design, the C–101. This missile is carried on the H–6 Xian bomber and can deliver a 500-kg warhead to a range of 80 km. *[Refs. 32, 103]*

YJ–1 and YJ–2

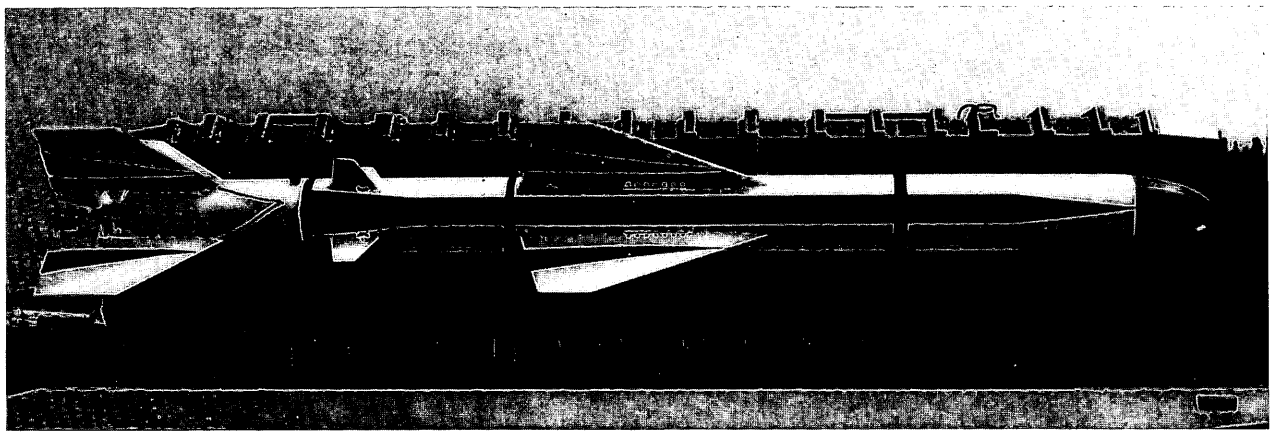
The YJ–1 is apparently based on the Exocet. It is a medium-range, radar-guided, solid-propellant missile. The original design was intended basically for shipborne or coastal defense applications but was later modified to provide an air-to-surface version. It has four clipped delta wings mid way down the body with four much smaller clipped-tip triangular control fins at the rear. The missile shape is similar to the Exocet, but the YJ–1 is heavier. It is 4.65 m long with a body diameter of 0.38 m and a wingspan of 1.65 m, weighs around 655 kg, and delivers a 165-kg warhead to a range of 40 km. The follow-on YJ–2 uses a turbofan for propulsion and has a range of 120 km. It has been sold to Thailand. *[Ref. 32]*

France



French missile transfers, although limited to cruise missiles, have been widespread. Exocets are being used by 29 navies and 13 air forces throughout the world. The ship-launched version was used by Argentina in the Falklands war and by Iraq in the Iran–Iraq war and in the U.S.S. *Stark* incident. The French are developing two new longer range cruise missiles for potential sale. Both originated as joint developments with Germany, but the Germans have subsequently withdrawn from the program.

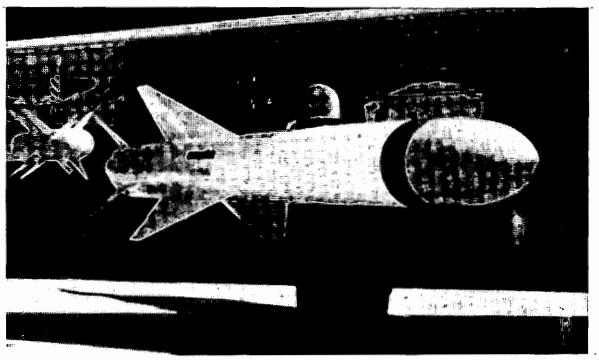
The Exocet MM 38 has four swept wings in a cruciform configuration at midbody and smaller control fins, also in cruciform, at the rear. The missile is launched from four-, six-, and eight-



JANE'S INFORMATION GROUP

YJ–1 (China)

canister containers carried onboard ships. The solid-propellant booster/sustainer cruises at an altitude of about 100 m with an inertial guidance system and then drops down to 10–15 m during the approach phase when the X-band radar seeker is locked on the target. The missile descends further to 2 to 5 m during the sea-skimming terminal phase. Both conventional HE and nuclear warheads are available for use on the Exocet with the HE warhead available for export. *[Ref. 32]*



JANE'S INFORMATION GROUP

Exocet (France)

The MM 38 is 5.21 m in length and has a body diameter of 0.35 m. It has a launch weight of 735 kg and delivers a 168-kg payload to a range of 40 km. The missile has been sold throughout the Middle East, in the Far East, and in South America as well as to European countries. *[Ref. 32]*

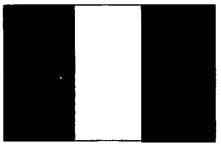
The MM 40 is a surface-launched missile with folded wings. Its booster is larger than that of the MM 38, increasing the overall length to 5.78 m and the maximum range to 70 km. *[Ref. 32]*

The AM 39 is a somewhat smaller air-launched version of the Exocet. It is 4.7 m long and 0.35 m in diameter, has a wingspan of 1.1 m and a launch weight of 652 kg, and delivers a 165-kg payload to 50 km. The AM 39 has four clipped delta wings at midbody and four raked clipped-tip moving delta control fins at the rear. The midcourse guidance phase is inertial, followed by active radar homing. The range of the AM 39 is 70 km when launched from an altitude of 10,000 m. *[Ref. 103]*

French Missile Sales

Missile	Range (km)	IOC	Customer
Surface-Launched			
Exocet MM 38	40	1975	Argentina, Belgium, Brazil, Brunei, Chile, Ecuador, West Germany, Greece, Indonesia, Iraq, South Korea, Malaysia, Morocco, Nigeria, Peru, Thailand, United Kingdom
Exocet MM 40	70	1981	Argentina, Bahrain, Brazil, Brunei, Cameroon, Colombia, Ecuador, Kuwait, Morocco, Oman, Qatar, Singapore, Tunisia, United Arab Emirates
Air-Launched			
Exocet AM 39	50	1978	Argentina, Egypt, Iraq, India, Kuwait, Libya, Oman, Pakistan, Peru, Qatar, Singapore, South Africa
AS–37	55	1970	Middle East (unconfirmed)
Armat	90	1984	Egypt, Iraq, Kuwait

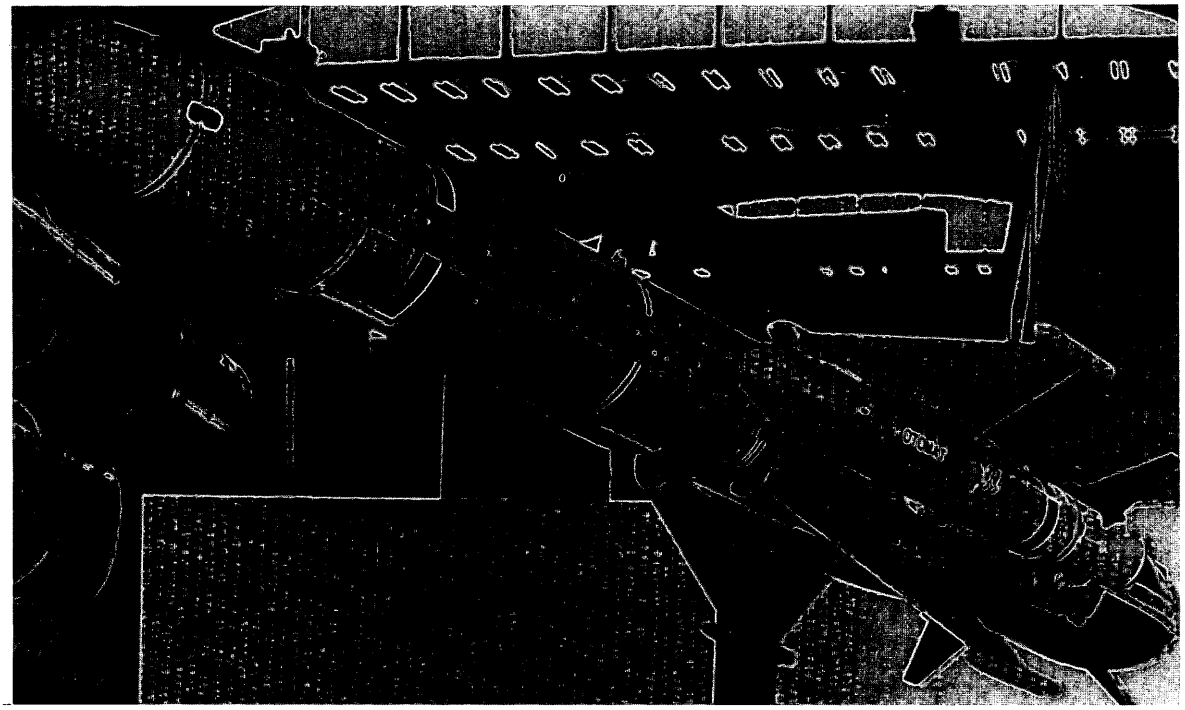
Italy



The Otomat is a joint Italian–French development. It is a short-range, ship- and ground-launched, turbojet-powered, single-warhead, surface-to-surface missile that uses external targeting sources to extend its maximum range. The missile is launched from canisters mounted shipboard or on truck bodies with two or four launchers per position. Two solid-propellant boosters push the missile up to an altitude of 150 to 250 m. It then descends to a 15- to 20-m cruise altitude. Command updates are used to retarget the missile during cruise, and the missile drops to a sea-skimming altitude for final approach. A variant, upon seeker lock, climbs to an altitude of 2,000 m and then dives on the target. Development of a supersonic version called Otomach is pending. *[Ref. 32]*

The Otomat has a cylindrical body with a blunt nose and turbojet engine intakes at the base. There are four delta-shaped wings at midbody and four clipped triangular moving control fins at the rear. The wings are fixed on the Mk 1 but folded on the Mk 2. The missile is 4.46 m long and has a body diameter of 0.46 m at its widest point. The launch weight with two jettisonable 75-kg booster motors and a 210-kg warhead is 770 kg. Guidance is inertial with a command update and an active radar. The Mk 1 has a range of 60 km; the Mk 2, 180 km. The Mk 2 is still in production. *[Ref. 32]*

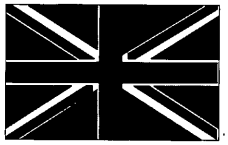
The Mk 1 entered service in 1976 and the Mk 2 in 1984; the latter is still in production. Over 930 missiles have been built or are on order. They have been sold to eight countries. *[Ref. 32]*



JANE'S INFORMATION GROUP

Otomat (Italy)

United Kingdom

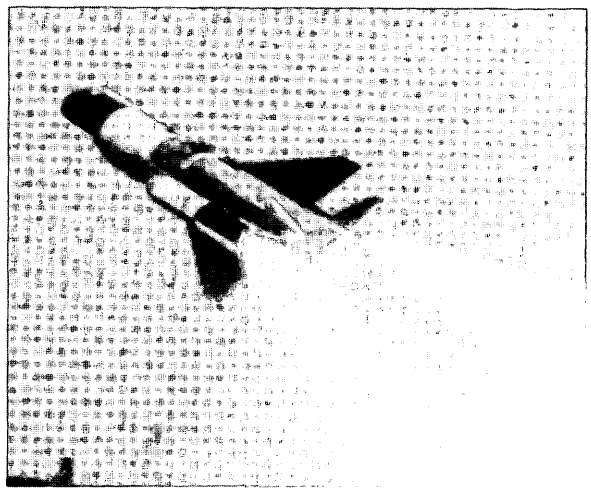


The United Kingdom has produced surface- and air-launched cruise missiles for export.

Sea Eagle

The Sea Eagle is a long-range, radar-guided, air-to-surface missile. It is propelled by a turbofan jet engine, augmented by solid-propellant boosters for the helicopter-launched version. The missile has four clipped delta wings aft of midbody closely followed by four clipped delta control fins. It is 4.14 m long with a body diameter of 0.4 m and a wingspan of 1.2 m. The missile weighs 600 kg and delivers an HE warhead to a range of 120 km. Inertial guidance is used for midcourse flight and a J-band active pulse radar seeker for terminal homing. The Sea Eagle entered service in 1985, is still in production, and currently resides in the inventories of India, Oman, and Saudi Arabia. *[Ref. 103]*

The ship-launched Sea Eagle version is derived from the helicopter-launched version. It is under development and has been offered to South Korea. *[Ref. 103]*

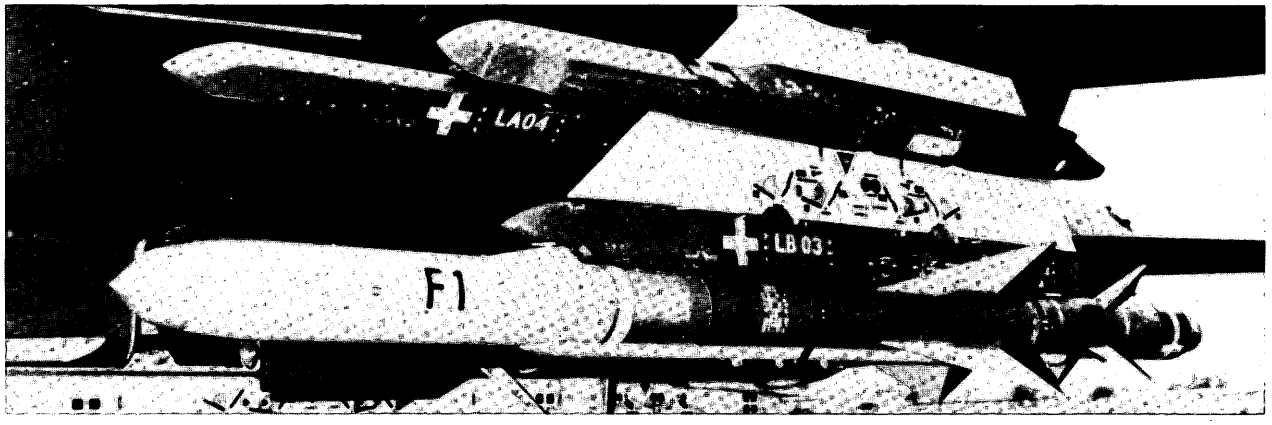


JANE'S INFORMATION GROUP

Sea Eagle (United Kingdom)

ALARM

The Air-Launched Anti-Radar Missile (ALARM) is a medium-range cruise missile with four small stabilizer fins at the nose, four delta wings aft of midbody, and four movable delta fins at the rear. It uses a solid-propellant motor. The missile is 4.3 m long and has a body diameter of 0.22 m and a wingspan of 0.72 m. It weighs 265 kg. Guidance is provided by a broadband passive radar seeker. Following launch, the missile climbs to altitude, coasts to the target area, and dives on the detected target. If no target is detected, the system has a limited loiter capability. The ALARM is believed to have entered service with the U.K. Royal Air Force in 1991. There are reports that the missile has been ordered by Saudi Arabia. *[Ref. 32]*



JANE'S INFORMATION GROUP

ALARM (United Kingdom)

United Kingdom Missile Sales

Missile	Range (km)	IOC	Customers
Surface-launched			
Sea Eagle SL	110	[illegible]	South Korea (uncontirmed or pending)
Air-launched			
ALARM	45	[illegible]	Saudi Arabia (uncontirmed or pending)
Sea Eagle	110	[illegible]	India, Oman, Saudi Arabia

Israel

The Israeli defense industry is one of the strongest in the Middle East. Its programs include ballistic missiles, space launch vehicles, and cruise missiles. The Gabriel family of cruise missiles have been offered for export, and sales have been confirmed to seven countries.

Israeli Missile Sales

Surface-Launched Missile	Range (km)	IOC	Customers
Gabriel Mk 1	20	1969	Singapore, Thailand
Gabriel Mk 2	35	1976	Chile, Ecuador, Kenya, Taiwan, South Africa
Gabriel Mk 3	35	1980	Chile

The Gabriel Mk 1 is a short- to medium-range antiship missile that entered service in 1969. It is a cruciform design with wings and fins and uses a single, solid-propellant, two-stage rocket motor. The missile is thought to use an I-/J-band active radar seeker with an optional "home-on-jam" capability. Guidance is provided by a gyroscope platform and a radio altimeter. The missile is 3.36 m long and 0.34 m in diameter, with a wingspan of 1.35 m. It has a launch weight of 430 kg and delivers a payload of about 100 kg to a range of about 20 km. The Israeli navy fired 55 Gabriel Mk 1s during the 1973 Middle East War with a claimed success rate of 85 percent. The missile has been sold to Singapore and Thailand. *[Ref. 32]*

JANES INFORMATION GROUP

Gabriel (Israel)

The Gabriel Mk 2, which entered service in 1976, has cruciform rectangular wings at midbody and four in-line cruciform rectangular control fins at the aft end. It uses solid-propellant booster and sustainer rockets and semi-armor-piercing HE warheads. After prelaunch targeting of the guidance system, the Mk 2 is launched and flown at a cruise altitude of about 100 m on autopilot. At a given distance from the ship, the missile descends to 20 m and maintains that altitude by use of an altimeter. When the semiactive, frequency-agile S-/J-band radar acquires the target, the missile descends to an altitude of 1 to 3 m, depending on wave height (sea state), for the final approach to the target. The Mk 2 is 3.41 m long and has a

launch weight of 520 kg and a range of about 36 km. The missile has been exported to Chile, Ecuador, and Kenya. It has also been manufactured in Taiwan as the Hsiung Feng (Male Bee) and in South Africa as the Skorpioen. *[Ref. 32]*

The Gabriel Mk 3 incorporates an advanced guidance system that provides additional targeting options. The missile is 3.81 m long and has a launch weight of 560 kg and a range of 36 km. The Mk 3 has been exported to Chile. *[Ref. 32]*

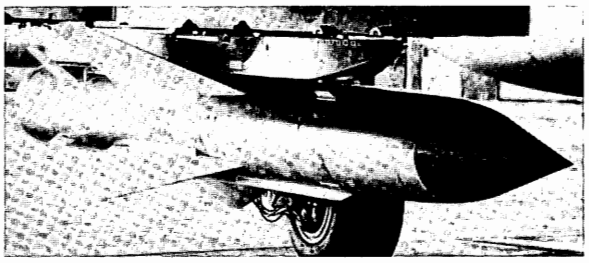
EMERGING SUPPLIERS

The emerging aerodynamic missile suppliers are those industrialized nations that have just begun selling—or trying to sell—missiles to other nations. Countries usually start selling cruise missiles before ballistic missiles since the former are easier to develop. Three countries have exported cruise missiles.

Germany

West Germany began several joint cruise missile development programs with France over the past few years, only to drop out later due to fiscal constraints, such as those resulting from its contributions to the Persian Gulf war and the cost of reunification with East Germany. The Apache and ANL both began as joint ventures and were subsequently abandoned by the Germans. German companies have also been reported as having assisted Libya with the Al Fatah ballistic missile and Iraq and others with their missile programs.

The AS–34 Kormoran air-launched cruise missile was developed as an antiship weapon. The Kormoran 1 has four clipped delta wings midbody and four clipped delta control fins in the rear of the missile. It cruises at an altitude of about 30 m using inertial guidance and a radar altimeter. The active radar seeker is initiated soon after launch. In the terminal mode, the missile dives to a sea-skimming altitude so that it can hit its target just below the water line. Semi-armor-piercing HE warheads are used with delayed fusing. *[Ref. 32]*

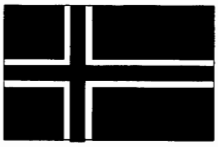


JANES INFORMATION GROUP

Kormoran (Germany)

The Kormoran is 4.4 m long, has a body diameter of 0.35 m, and has a wingspan of 1.0 m. It weighs 600 kg and delivers a 165-kg payload to a range of 35 km. The Kormoran 1 entered service with the West German navy in 1977, and 350 missiles were delivered. In addition, the Italian air force ordered about 60 missiles. Production ceased in 1983. A follow-on missile is known as the Kormoran 2. *[Ref. 32]*

Norway

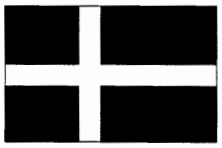


Norwegian missile development activity has centered around the Penguin, which began as a relatively inexpensive, easy-to-operate antiship cruise missile designed to be carried on smaller warships. Two to six missiles are carried, depending on the size of the vessel. The Penguin Mk 1 is a cruciform canard configuration with four swept-wing control fins up front and four delta wings just aft of the midbody. The rounded leading-edge wings incorporate ailerons for roll stabilization. The booster and sustainer motors are integral and use solid propellants. The missile is accelerated to cruise speed and altitude and then sustained there. When the IR seeker acquires and locks on the target, the missile descends to sea-skimming altitude for the terminal phase. The warhead uses semi-armor-piercing HE. The Mk 2 version has an improved IR seeker and uses microprocessing to enhance the performance of electronic counter-countermeasures and to allow angled trajectories. *[Ref. 32]*

The Penguin is 2.96 m long, has a diameter of 0.28 m and a wingspan of 1.42 m, and weighs 385 kg. Midcourse guidance is inertial with a radio altimeter. The missile has a passive IR terminal seeker. The range of the Mk 1 is 18 km; the range of

the Mk 2 is over 30 km. The Penguin Mk 1 entered service in 1972 and the Mk 2 in 1980. The former has been exported to Turkey, and the latter to Greece and Sweden. *[Ref. 32]*

Sweden



The Swedish RBS–15 is a versatile antiship missile system developed for three distinct missions: coastal defense, ship to ship, and air to ship. The RBS–15 is basically a replacement for the radar-guided RB04 and command-guided RB05 cruise missiles, which were never exported.

The RBS–15 has four canard fins near the nose for yaw control and four cruciform wings with ailerons at the rear for pitch and roll control. A large air inlet for the turbojet engines is located under the body forward of the wings. The missile is accelerated to cruise speed with two solid-propellant motors. After jettisoning of the boosters, an autopilot and altimeter are used to retain trajectory and control height. In the terminal phase, the missile locks on the target and follows a sea-skimming approach using passive home-on-jam or active radar homing. The active radar seeker is a frequency-angle J (Ku)-band system. The warhead can be semi-armor-piercing or blast-fragmented HE. *[Ref. 32]*

The RBS–15 is 4.35 m long and 0.5 m in diameter. Its wingspan is 1.4 m. It has a launch weight of 598 kg and delivers a 200-kg warhead to a range of 90 km. The ship-launched version entered service with the Royal Swedish Navy in 1985, followed by the air-launched version the next year. The weapon has been exported to Finland and possibly to Yugoslavia. *[Ref. 32]*

OTHER INDIGENOUS AERODYNAMIC MISSILE PROGRAMS

Five other countries—Brazil, Iraq, Japan, South Africa, and Taiwan—have indigenous cruise missile efforts. They are not known to be exporting their missiles.

Other Indigenous Missiles

Country	Missile	Range (km)	IOC	Status and Comments
Surface-Launched				
Brazil	SM–70 Barracuda	70	TBD	
Iraq	FAW 70	80	1991	SS–N–2C Styx-based
	FAW 150	150	1991	
	FAW 200	200	1991	
Japan	SSM–1	150	1988	Gabriel Mk 2-based
	SSM–1B and –2	150	Mid 1990s	
South Africa	Skorpioen	35	—	Gabriel Mk 2 manufacturing line
Taiwan	Hsiung Feng–1	35	1980	Gabriel Mk 2 manufacturing line
	Hsiung Feng–2	80	1993	Harpoon-based
Air-Launched				
Iraq	Ababeel	500		
Japan	ASM–1 (Type 80)	50	1983	
	ASM–2 (Type 88)	150	1995	In design phase
Taiwan	Hsiung Feng–2	80	1993	In test phase/Harpoon-based

References

1. Kenneth P. Werrell, *The Evolution of the Cruise Missile,* Air University Press, September 1985.
2. Richard K. Betts, ed., *Cruise Missiles: Technology, Strategy, Politics,* The Brookings Institution, 1981.
3. Frederick I. Ordway III and Mitchell R. Sharpe, *The Rocket Team,* Massachusetts Institute of Technology, 1982.
4. Donald E. Fink, ed., "Give Patriot Credit Where Due," *Aviation Week,* May 13, 1991.
5. Donald MacKenzie, *Inventing Accuracy: A Historical Sociology of Nuclear Missile Guidance,* Massachusetts Institute of Technology, 1990.
6. Winston Churchill, *Triumph and Tragedy,* Houghton, Boston, 1981.
7. *Assessing Ballistic Missile Proliferation and Its Controls* (Draft), Center for International Security and Arms Control, Stanford University Press, November 1991.
8. Joseph Bermudez, "Ballistic Missiles in the Third World—Egypt and the 1973 Arab–Israeli War," *Jane's Intelligence Review,* vol. 3, no. 12, December 1991.
9. Anthony H. Cordesman and Abraham R. Wagner, *The Lessons of Modern War: The Arab–Israeli Conflicts, 1973–1989,* vol. I, Westview Press, Boulder, 1990.
10. Chaim Herzog, *The Arab–Israeli Wars,* Random House, New York, 1982.
11. John Wilson Lewis and Xue Litai, *China Builds the Bomb,* Stanford University Press, 1988.
12. Mark Wade, "The Chinese Ballistic Missile Program," *International Defense Review,* vol. 13, no. 8, August 1980.
13. Anthony H. Cordesman and Abraham R. Wagner, *The Lessons of Modern War: The Afghan and Falklands Conflicts,* vol. III, Westview Press, Boulder, 1990.
14. Max Hastings and Simon Jenkins, *The Battle for the Falklands,* Norton, New York, 1983.
15. Martin Middlebrook, *The Fight for the "Malvinas": The Argentine Forces in the Falklands War,* Penguin Books, London, 1989.
16. W. Seth Carus, *Ballistic Missiles in Modern Conflict,* published with the Center for Strategic and International Studies, Praeger, New York, 1991.
17. U.S. Department of Defense, *Conduct of the Persian Gulf Conflict: An Interim Report to Congress,* July 1991.
18. Anthony H. Cordesman and Abraham R. Wagner, *The Lessons of Modern War: The Iran–Iraq War,* vol. II, Westview Press, Boulder, 1990.
19. David C. Isby, "Soviet Advisers in Afghanistan—The Involvement Continues," *Jane's Intelligence Review,* vol. 3, no. 6, June 1991.
20. "Communique 39 Reviews Joint Forces Operations," FBIS–NES–91–039, February 22, 1991.
21. "Technology Gap Between Israel, Arab States Viewed," JPRS–NEA–90–017, March 21, 1990.
22. Joseph Bermudez, "Ballistic Missiles in the Third World—Afghanistan 1979–1992," *Jane's Intelligence Review,* vol. 4, no. 2, February 1992.
23. Steven Zaloga, "Ballistic Missiles in the Third World: Scud and Beyond," *International Defense Review,* vol. 21, no. 11, November 1988.

24. Keith Payne, *Missile Defense in the 21st Century: Protection Against Limited Threats,* Westview Press, Boulder, 1991.

25. John M. Goshko and Trevor Rowe, "U.N. Panel Describes Iraq's Anthrax Threat," *The Washington Post,* August 15, 1991.

26. Susan Wright, ed., *Preventing a Biological Arms Race,* Massachusetts Institute of Technology, 1990.

27. Duncan Lennox, ed., *Jane's Strategic Weapons Systems,* Jane's Information Group, Surrey, U.K., 1990.

28. The International Institute for Strategic Studies, *The Military Balance, 1990–1991,* Brasseys, 1991.

29. Institute for Defence & Disarmament Studies, "Update to Ballistic Missile Proliferation," *Arms Control Reporter,* Cambridge, MA, September 1991.

30. Bill Gertz, "Libya May Buy N. Korean Missiles," *The Washington Times,* June 4, 1991.

31. Joseph Bermudez, "New Developments in North Korean Missile Programme," *Jane's Soviet Intelligence Review,* vol. 2, no. 8, August 1990.

32. Duncan Lennox, ed., *Jane's Strategic Weapon Systems,* Jane's Information Group, Surrey, U.K., 1991.

33. Duncan Lennox, "China's Development of Ballistic Missiles," *Jane's Intelligence Review,* vol. 3, no. 8, August 1991.

34. Elaine Sciolino and Eric Schmit, "China Said To Sell Parts for Missiles," *The New York Times,* January 31, 1992.

35. Paul Lewis and David Silverberg, "West Worries China Will Sell Missiles," *Defense News,* March 1992.

36. Joseph Bermudez, "Syria's Acquisition of North Korean 'Scuds'," *Jane's Intelligence Review,* vol. 3, no. 6, June 1991.

37. Martin Navias, "Ballistic Missile Proliferation in the Third World," *Adelphi Papers 252,* Summer 1990.

38. W. Seth Carus and Joseph Bermudez, "Iraq's Al-Husayn Missile Programme," *Jane's Soviet Intelligence Review,* vol. 2, nos. 5 and 6, May and June 1990.

39. Aaron Karp, "Ballistic Missile Proliferation," *SIPRI Yearbook 1991: World Armaments and Disarmament,* SIPRI, 1991.

40. W. Seth Carus and Joseph Bermudez, "Iran's Growing Missile Forces," *Jane's Defence Weekly,* vol. 10, no. 3, July 23, 1988.

41. Bill Gertz, "Iran–Syria Deal Revealed as Scuds Near Gulf Ports," *The Washington Times,* March 10, 1992.

42. Bill Gertz, "N. Korean Freighter Arrives in Iran With Scuds for Syria," *The Washington Times,* March 11, 1992.

43. Robert Rudney, "Argentina's Condor 2 Missile: Dead, Dying, or Waiting in the Wings?" *Armed Forces Journal International,* September 1991.

44. Mark Hewish, ed., *International Defense Review,* vol. 24, no. 8, August 1991; vol. 25, no. 8, August 1992.

45. Robert Shuey et al., *Missile Proliferation—Survey of Emerging Missile Forces,* Congressional Research Service, 88–642F, February 9, 1989.

46. Gary Milhollin, "India's Missiles—With a Little Help From Our Friends," *The Bulletin of Atomic Scientists,* November 1989.

47. Aaron Karp, "Ballistic Missile Proliferation in the Third World," *SIPRI Yearbook 1989: World Armaments and Disarmament,* SIPRI, 1989.

48. Peter Howard, ed., *Jane's Defence Weekly,* vol. 16, no. 7, August 1991.

49. Kathleen Bailey, "Ballistic and Cruise Missiles: Hard To Develop?" and "Missile Proliferation: Who and Why," *Doomsday Weapons in the Hands of Many: The Arms Control Challenge of the 90s,* University of Illinois Press, Chicago, 1991.

50. W. C. Potter, *Soviet Nuclear Salesmen,* Monterey Institute of International Studies, October 21, 1991.

51. Janne Nolan, *Trappings of Power: Ballistic Missiles in the Third World*, The Brookings Institution, Washington, D.C., 1991.

52. Duncan Lennox, "Iraq's 'Scud' Programme—The Tip of the Iceberg," *Jane's Defence Weekly,* vol. 15, no. 10, March 2, 1991.

53. Joseph Bermudez and W. Seth Carus, "The North Korean 'Scud B' Programme," *Jane's Soviet Intelligence Review,* vol. 1, no. 4, April 1989.

54. Kathleen Bailey, *Doomsday Weapons in the Hands of Many: The Arms Control Challenge of the 90s*, University of Illinois Press, 1991.

55. International Missile Proliferation Project, "Missile Capabilities of Selected Countries," *Missile Monitor,* Fall 1991.

56. Institute for Defence & Disarmament Studies, "Update on Missile Proliferation," *Arms Control Reporter,* Cambridge, MA, November 1991.

57. David Silverberg, "Iranian Arms Buildup Concerns U.S.," *Defense News,* 2 March 1992.

58. Andrew Wilson, ed., *Interavia Space Directory (1991–92)*, Jane's Information Group, London, 1991.

59. Aaron Karp, "Ballistic Missiles in the Third World," *International Security,* Winter 1984–85.

60. Thomas Mahnken, "Why Third World Space Systems Matter," *Orbis,* Fall 1991.

61. "Arms Sales to the Middle East Since the Gulf War," *Senate Congressional Record,* vol. 137, no. 171, GPO, Washington, D.C., November 19, 1991.

62. Fred Donovan, "Mideast Missile Flexing," *Arms Control Today,* May 1990.

63. John W. R. Taylor, "Gallery of Soviet Missiles," *Air Force Magazine,* vol. 74, no. 6, June 1991.

64. BG Aharon Levran (Ret.), "Threats Facing Israel from Surface-to-Surface Missiles," *IDF Journal,* Winter 1990.

65. Thomas McNaugher, "Ballistic Missiles and Chemical Weapons: The Legacy of the Iran–Iraq War," *International Security,* Fall 1990.

66. Joseph Alpher et al., "The Middle East Military Balance, 1989–1990," *Jerusalem Post Press,* Israel, 1990.

67. Joseph S. Bermudez, Jr., "Iraqi Missile Operations During 'Desert Storm'—Update," *Jane's Soviet Intelligence Review,* vol. 3, no. 5, May 1991.

68. John Tagliabue, "Iraqi Weapons Had Chemical Warheads," *The New York Times,* November 12, 1991.

69. David Leppard et al., "Saddam Helps Algeria Make Islamic Nuclear Bomb," *London Sunday Times,* January 5, 1992.

70. John McCain, "Proliferation in the 1990s: Implications for U.S. Policy and Force Planning," *Strategic Review*, Summer 1989.

71. R. Jeffrey Smith, "Officials Say Iran Is Seeking Nuclear Weapons Capability," *The Washington Post,* October 30, 1991.

72. C. A. Robins, "The X Factor in the Proliferation Game," *U.S. News and World Report,* March 16, 1992.

73. Janne E. Nolan and Albert D. Wheelon, "Third World Ballistic Missiles," *Scientific American,* vol. 263, no. 2, August 1990.

74. Aaron Karp, *The United States and the Soviet Union and the Control of Ballistic Missile Proliferation to the Middle East*, Institute for East–West Security Studies, New York, 1990.

75. Nick Cook et al., "Iraq—A Special Report," *Jane's Soviet Intelligence Review,* vol. 2, no. 10, October 1990.

76. E. Hooton, ed., *Janes Naval Weapon Systems,* Jane's Information Group, Surrey, U.K., 1990.

77. H. W. Graves, *Nuclear Fuel Management,* John Wiley & Son, Inc., New York, 1979.

78. Steven Emerson, "The Postwar Scud Boom," *The Wall Street Journal,* July 10, 1991.

79. Bill Gertz, "North Korean Scuds Added to Syrian Arsenal," *The Washington Times,* March 13, 1991.

80. N. Friedman, *The Naval Institute Guide to World Naval Weapons Systems 1991/92,* Naval Institute Press, Annapolis, 1991.

81. John Lewis et al., "Beijing's Defense Establishment: Solving the Arms-Export Enigma," *International Security,* Spring 1991.

82. Peter Howard, ed., "Satellite Captures First Views of Saudi CSS–2 Missile Sites," *Jane's Defence Weekly,* October 1, 1988.

83. W. Seth Carus, *Ballistic Missiles in the Third World: Threat and Response,* Praeger, New York, 1990.

84. George E. Brown et al., *Global Arms Trade,* Office of Technology and Assessment, OTA–ISCl–460, Washington, D.C., June 1991.

85. Duncan Lennox, "China's Development of Ballistic Missiles," *Jane's Intelligence Review,* vol. 3, no. 8, August 1991.

86. Richard Bitzinger, *Chinese Arms Production and Sales to the Third World,* Rand Note N–3334–USDP, 1991.

87. "North 'World's Seventh Biggest' Arms Exporter," JPRS–TND–91–0111, July 24, 1991.

88. Sharon Denny, ed., "SDIO Seeks Advanced ATBM Capabilities for Near Term," *Defense News,* vol. 6, no. 8, February 25, 1991.

89. Larry Zurriff, "Confrontations in Ballistic Missile Proliferation," *Brown Foreign Affairs Journal,* vol. 3, no. 2, Brown University, Spring 1991.

90. Amit Gupta, "Fire in the Sky: The Indian Missile Program," *Defense and Diplomacy,* October 1990.

91. "Sindhi's Urge Indo–Pak Unity for Casting Subcontinental Peace," JPRS–NEA–90–072, December 6, 1990.

92. Raju G. C. Thomas, *Indian Security Policy,* Princeton University Press, Princeton, 1986.

93. Steven Coll, "South Asia Retains Its Nuclear Option," *The Washington Post,* September 30, 1991.

94. Maynard Parker, ed., "Saddam's Nuclear Secrets," *Newsweek,* October 7, 1991.

95. R. Jeffrey Smith, "Chinese Missile Launchers Sighted in Pakistan," *The Washington Post,* April 6, 1991.

96. Joseph Bermudez, "North Korea's HY–2 'Silkworm' Programme," *Jane's Soviet Intelligence Review,* vol. 1, no. 5, May 1989.

97. "Nuclear-Related Test Explosion Reported in North," FBIS–EAS–91–124, June 27, 1991.

98. "North Said To Possess 1,000 Tons of Warhead," FBIS–EAS–91–135, July 15, 1991.

99. Yevgeni Velikhov et al., *Weaponry in Space: The Dilemma of Security,* Mir Publishers, Moscow 1986.

100. Andrew Mack, "North Korea and the Bomb," *Foreign Policy,* no. 83, Summer 1991.

101. D. Hickey, "American Technology Assistance, Technology Transfers, and Taiwan's Drive for Defense Self-Sufficiency," *Journal of Northeast Asian Studies,* Fall 1989.

102. Leonard Spector, *Nuclear Ambitions,* Westview Press, Boulder, 1990.

103. Duncan Lennox and A. Rees, eds., *Jane's Air-Launched Weapons,* Jane's Information Group, Surrey, U.K., 1990.

104. David J. Meyers, quoted in Edward A. Kolodziej and Robert E. Harkavy, *Security Policies of Developing Countries,* Lexington Press, Lexington, MA, 1982.

105. "Cuba Contract for Missiles Export Alleged," JPRS–TND–91–005, March 18, 1991.

106. Andrew Pollack, "Advances on the Gyroscope Front," *The New York Times,* October 30, 1991.

107. Harvey Walters, "The GPS Buyer's Guide," *Cruising World*, July 1991.

108. Mark Hewish, ed., advertisement for Rafael Weapon Systems, *International Defense Review,* August 1992.

109. Robert Shuey et al., *Middle East Arms Control and Related Issues,* Congressional Research Service, Foreign Affairs and National Defense Division, 91–384 F, May 1, 1991.

110. Geoffrey Kemp, *The Control of the Middle East Arms Race,* Carnegie Endowment for International Peace, New York, 1991.

111. J. Smith, "Saddam's Nuclear Weapons Dream," *The Washington Post,* October 13, 1991.

112. Arnaud de Borchgrave, "3rd World Cash Buys Soviet Nuke Expertise," *The Washington Times,* December 10, 1991.

113. Reuters News Service, "Soviets Reported Trying To Sell A-Materials," Rome, Italy, December 30, 1991.