CHAPTER 4

PAKISTAN: UNDERSTANDING THE 'WORLD'S FASTEST GROWING ARSENAL'

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The goal of this chapter is to summarize the current Pakistani warhead, missile, and aircraft situation—to the extent that it is known from published sources—and then to enumerate various constraints that might limit a still larger increase. The forces pushing expansion are discussed.

Claims that Pakistan's nuclear arsenal has become the world's fastest growing one have reverberated around the world. In 2011, *The Washington Post*[1] put Pakistan's stockpile at more than 100 deployed weapons, a doubling over the past several years. Those figures made Pakistan the world's fifth-largest nuclear power. A second estimate, published in the *Bulletin of Atomic Scientists* report entitled: 'Pakistan's Nuclear Forces—2011'[2] by the Federation of American Scientists, states that although the numbers of Pakistani warheads and delivery vehicles is a closely held secret, yet 'we estimate that Pakistan has a nuclear weapons stockpile of 90–110 nuclear warheads, an increase from the estimated 70–90 warheads in 2009.' The authors reckon that if the expansion continues, Pakistan's stockpile could reach 150–200 in a decade.[3] By this count, Pakistan's arsenal may have already exceeded India's, and will soon rival Britain's.

Similar statements have been made earlier as well. A former top official of the CIA is quoted in the September 2009 *Bulletin of the Atomic Scientists* as saying, 'It took them roughly 10 years to double the number of nuclear weapons, from roughly 50 to 100.'[4]

The first question is: how do these Western analysts and officials arrive at these estimates? Why should we believe their numbers?

Obviously all nuclear activities is inside buildings to which access is strictly forbidden, and every precaution is made to shield them from prying eyes in the sky (and sometimes on the ground). The security around nuclear installations can be quite fearsome. So, for example, on 26 June 1979 France's ambassador to Pakistan had his teeth knocked out while trying to drive by the forbidden area near the Kahuta Research Laboratory (KRL). In addition to many other security requirements, KRL workers are required to report not just on those colleagues who spend too much time with friends, but also on those who stare outside the narrow windows for too long.

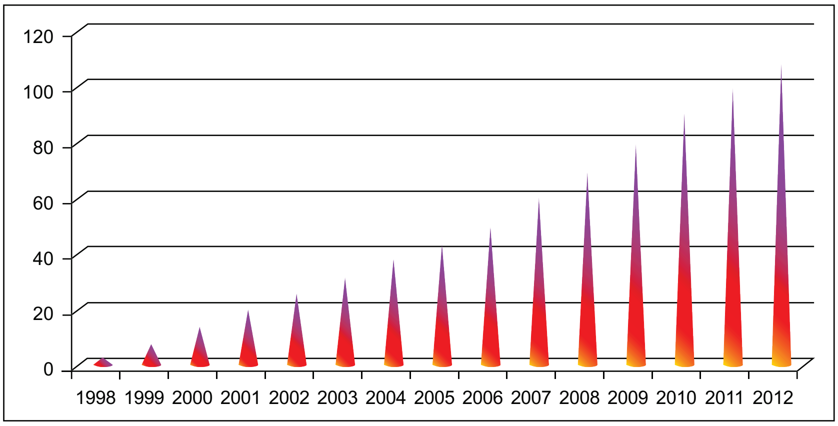
Still, some things are impossible to hide from prying eyes: there are tell-tale signatures of nuclear activities and the trained analyst knows just what to look for. High resolution satellite pictures can give overall physical details of buildings, plants, and machinery; electricity consumption results in a thermal signature detectable by infrared satellite cameras; sensors secretly placed around a plant can detect various kinds of gases; trucks and cars going in and out can be seen; communications can be electronically monitored; and movements of materials can be monitored. And, of course, there are spies—euphemistically called HI or 'human intelligence'. Professionals can then piece together the various evidences available.

Estimations can be inaccurate at times for a variety of reasons. A country can use subterfuges to conceal fissile material—the stuff out of which bombs are made. Their quantity and purity, as well as warhead and missile details are hard to know from afar. High resolution satellites can also be fooled, and human intelligence can be used in a way to manipulate figures. Thus, at the end of the day, one has only estimates and preconceptions by which to go on. But, strangely enough, these estimates have turned out to be rather good in some cases—as when they were made for the U.S. and France. The in-depth penetration of Iran's program, proved by the U.S.'s engineered destruction of Iranian centrifuges using the Stuxnet virus, is another example of intelligence success. This rather tenuous argument does not guarantee, of course, that estimates made by U.S. analysts will resemble reality for India, Pakistan, China, or Israel. But since governments generally do not divulge atomic secrets, perhaps it is better to have ballpark figures rather than no figures.

Pakistan has not denied *The Bulletin's* report. Its stockpile of bomb-grade HEU (Highly Enriched Uranium) is increased daily by the unknown thousands of centrifuges whirring away at the enrichment facility at Kahuta (KRL) some forty miles from Islamabad, as well as those rumoured to be elsewhere. A different kind of bomb material, plutonium, is produced by reactors located at Khushab in the province of Punjab. Two reactors are already at work and a third is undergoing trials. A fourth one is under construction, as anyone who can use Google Earth will confirm. The plutonium has no commercial purpose. Instead, the goal is to produce lighter and more compact bombs to be fitted on to missile tips.

In Graph I the current estimate of Pakistan's nuclear arsenal is given. It is, of course, subject to the caveats mentioned above. The numbers for earlier years appear to be underestimated; the first nuclear weapon dates to 1985–1986, and six had been tested in 1998.[2] Clearly there could not have been just two bombs left in the

Graph 1: Growth of Pakistan's Nuclear Arsenal



Data from *Bulletin of the Atomic Scientists* 2011 67: 91 by Hans M. Kristensen and Robert S. Norris in: 'Pakistan's Nuclear Forces, 2011'.

arsenal after the test. So a pinch of salt is called for! The subsequent rate of growth appears plausible, however.

Given that most nuclear states choose not to announce limits upon the size of its nuclear arsenal, one can safely assume that Pakistan's targets are similarly open-ended. Subject to material and technical constraints, Pakistan will seek to make as many warheads as possible, as well as make them more powerful and efficient. Hence more bomb material is being sought.

India's push for nuclear improvements and changing military doctrines almost immediately draw Pakistani reaction. A Wikileaks cable sent to Washington from the U.S. embassy in Islamabad said that Indian missile defense is a cause for worry in Pakistan: 'Pakistani counterparts point to India's interest and investment in missile defense, even if it will take many years to field a capable system. They believe this indicates that India is not interested in a balance of power, but intends to degrade the value of Pakistan's nuclear deterrent.'[5] But, given the near impossibility of defense in a situation where missile flight times are a mere 4–6 minutes, this cannot be a genuine concern. It also appears that Pakistan, quite wisely, is not worried by U.S. plans to sell the Patriot Advanced Capability 3 missile defense system to India. According to General Musharraf, the Patriot system also has a response time of up to eighteen minutes, while Pakistani missiles could begin landing within six minutes. Further, 'to top it all, our capability, which we have tested and is no secret, goes in the atmosphere. And when it drops down, it sheds its body in the air. The remaining part is the warhead, which is as small as 10 feet, and hard to hit.'[6]

'Cold Start' is of greater significance. This is an operation conceived by the Indian military in response to more Mumbai-type attacks. Pakistan has now made it known that the response to an invasion by Indian conventional forces could result in a nuclear riposte on the battlefield. But battlefield weapons are very uneconomical in terms of their fissile material requirements, and hence it has still greater need for fissile materials.

WHAT ELSE DRIVES THE EXPANSION?

United Nations Secretary-General Ban Ki-Moon is said to be a calm man. But Moon could not hide his frustration at Pakistan's determined opposition to a treaty that would limit fissile material production for use in nuclear weapons.[7] For three years, Pakistan has single-handedly—and successfully—blocked the Conference on Disarmament (CD) in Geneva from discussing an effort that would put a cap on fissile materials. Consequently, within diplomatic circles, Pakistan has acquired the reputation of an obstructionist that opposes all efforts towards this end.

Pakistan, in defending itself against these charges at the Conference on Disarmament in Geneva, cites the U.S.–India nuclear deal,[8,9] along with older issues related to verification problems and existing stocks, as its principal objection to the FMCT (Fissile Material Cut-off Treaty). Indeed, the Deal was a powerful blow against international arms control. The United States, while pursuing its perceived national interests, had chosen to commit itself to nuclear cooperation with India—a state that had not signed the NPT, and one that made nuclear weapons surreptitiously using technology given to it for exclusively peaceful purposes. America now had to choose between supporting the integrity of the NPT, which it had initiated and pushed for in the 1960s, against its more recent desire to achieve a new strategic balance in Asia in the post-Cold War world. After some initial hesitation, it chose the latter.

Mainstream India was delighted at the Deal, although the Indian Left noisily protested. The sanctions imposed after the 1998 tests had been lifted after India's vehement protestations but now, under the Deal, India wanted much more—such as importing advanced nuclear reactor technology, as well as natural uranium ore from diverse sources including Australia.[10] Although imported ore cannot legally be used for bomb-making, India can in principle divert more of its scarce domestic ore towards military reactors. Joseph Cirincione of the Centre for American Progress, and a critic of the Deal, remarked:

> The deal endorses and assists India's nuclear-weapons program. United States supplied uranium fuel would free up India's limited uranium reserves for fuel that otherwise would be burned in these reactors to make nuclear weapons. This would allow India to increase its production from the estimated six to 10 additional nuclear bombs per year to several dozen a year.[11]

The Deal is inimical to the objective of a world with fewer nuclear weapons. But this may not be the full story; another powerful incentive now lies behind Pakistan's forceful rejection of the FMCT, one having to do with America rather than India. Whereas formally the U.S. and Pakistan are still allies in the War Against Terror announced by President G.W. Bush after the 9/11 attacks on U.S. soil, they have long loitered at the brink of open hostility. *The Washington Post* columnist David Ignatius writes that, 'United States and Pakistan have the most neurotic, mutually destructive "friendly" relationship in the world.'[12]

Today, in the Pakistan military's mind, the threat posed by the U.S. competes with that from India. Although TTP (Tehreek-e-Taliban Pakistan) jihadists have killed thousands of Pakistani troops and civilians over the last four–five years, the Americans are considered still more of an adversary. Smarting after U.S. troops intruded into Pakistan and killing Osama bin Laden, General Ashfaq Pervez Kayani reminded the Americans that Pakistan was a nuclear power and should not be compared with Iraq or Afghanistan and to 'think 10 times' before moving into the North Waziristan region from Afghanistan.[13]

Conflict with the U.S. is a possibility that Pakistanis frequently wonder about. Pakistan's former ambassador to the U.N., Munir Akram, hints that this may not be far away:

> Today, the relationship has passed into the zone of hostility at the popular and official level. It is entirely uncertain where the American insults, collaboration with our regional adversaries and talk of 'losing patience' with Pakistan will lead. The history of the nuclear era reveals how often states have come, through blunder and miscalculation, to the brink of nuclear catastrophe.[14]

A major reason for the Pakistan Army's growing hostility towards the U.S. is the increasing conviction that its nuclear weapons are threatened by America. This perception is reinforced by the decade-long attention given to the issue in the U.S. mainstream press, and by war-gaming exercises in U.S. military institutes. Pakistani fears about a weapon-snatch skyrocketed after the bin Laden raid in Abbotabad in May 2011. Two weeks later Senator John Kerry, Chairman of the Senate Foreign Relations Committee, came to Islamabad. His visit was reported to be a tense one:

> Kayani was still seething. He used a private session with Kerry and Pakistan's president and prime minister to demand a written assurance that, under no circumstances—even chaos in Pakistan—would the United States enter the country to grab or secure the country's nuclear treasure. Kerry, thinking he was using a figure of speech, said he was prepared to 'write in blood' that the United States had no intention to go after the arsenal.[15]

Of course, an American attack on Pakistan's nuclear facilities is very improbable. It is difficult to imagine any circumstances—except possibly the most extreme—in which the U.S. would risk going to war against another nuclear state. Even if Pakistan had just a handful of weapons, no outside power could accurately know the coordinates of the mobile units on which they are located. Immediately after the bin Laden killing, Americans detected that elements of the arsenal had been moved around.[16] According to *The Atlantic*:

> Nuclear-weapons components are sometimes moved by helicopter and sometimes moved over roads. And instead of moving nuclear material in armoured, well-defended convoys, the SPD prefers to move material by subterfuge, in civilian-style vehicles without noticeable defenses, in the regular flow of traffic. According to both Pakistani and American sources, vans with a modest security profile are sometimes the preferred conveyance. And according to a senior U.S. intelligence official, the Pakistanis have begun using this low-security method to transfer not merely the 'de-mated' component nuclear parts but 'mated' nuclear weapons.[17]

For any attacker, mobile dummies and decoys hugely compound difficulties. Additionally, General Musharraf revealed to American journalist Seymour Hersh that an extensive network of underground tunnels exists: 'The tunnels are so deep that a nuclear attack will not touch them.[18] Within these warheads and missile launchers can be freely moved. Moreover, even if a nuclear location was exactly known, it would surely be heavily guarded. This implies many casualties if intruding troops are engaged, thus making a secret Osama bin Laden type operation impossible.

Although Pakistan's preparations make for a formidable defense and an American attack is unlikely, all armies prepare for contingencies. Post-Osama bin Laden, the Pakistan Army's deepest nightmare is to be stripped of its nuclear weapons. Thus, redundancy is considered desirable—an American attempt to seize or destroy all warheads would have smaller chances of success if Pakistan had more. Hence the impetus for expanding the arsenal increases.

NUCLEAR WARHEADS

Let us take a look at the available information on Pakistan's warhead production, beginning with some general facts. Two types of fission bombs exist. For a Hiroshima sized effect, uranium-based weapons typically need 15–25 kg of HEU with 90 per cent purity or better which, if solidly packed, is about the size of a grapefruit. Plutonium-based weapons can achieve the same power with just 3–5 kg, which is golf-ball sized, and can therefore have more explosive yield in smaller, lighter, packages. Pakistan wants warheads small enough to fit on the cruise missiles it is currently developing.

The maximum number of uranium-based warhead cores that can be produced by Pakistan depends on the quantity of HEU produced in centrifuges at the Kahuta enrichment facility, and perhaps at other undeclared facilities elsewhere in Pakistan. The initial HEU production was achieved using replicas of the aluminium P-1 centrifuge, brought from Europe by A.Q. Khan in the mid-1970s. This had a capacity of less than one 'Separative Work Unit (SWU)' but was initially the mainstay of the centrifuge program. It was supplemented in the late 1980s by the P-2 model which had a throughput of up to 5 SWU's. Typically, centrifuges are cascaded together in groups of approximately 164; in turn one group feeds into another until the desired enrichment is obtained. It takes roughly 5000 SWU to make 25 kg of 90 per cent HEU, which is enough for a bomb.

More advanced centrifuges with faster rotor speeds, made possible by using stronger (maraging) steels, were subsequently made at the Kahuta Research Laboratory (KRL).[19] The P-3 was the first of the two later centrifuges. It is a four-tube model with a throughput of just under 10 SWU/yr. According to the reference just cited, the P-4, which is still more advanced, may have a throughput of about 20 SWU/yr. Although there is information about the types of these centrifuges in operation, their numbers are not known but are almost certainly in the few thousands by now. One therefore expects that the yearly production rate of HEU is currently several times larger than in the mid 1980s and that it will keep expanding.

To feed the centrifuges one needs uranium in gaseous form (or, more accurately, uranium hexafluoride UF_6). The amount of natural uranium mined from presently known deposits, principally in the district of Dera Ghazi Khan, is currently enough to sustain the bomb program. But that is because the civilian use is low—the Chashma reactors have fuel supplied by China. Pakistan has declared to the IAEA that it mines 40 tons of uranium ore yearly.[20] This is distributed between fuel fabrication for the Karachi Nuclear Power Plant (KANUPP) and for fissile material production in military reactors; much more mining will be needed if Pakistan's civilian nuclear program ever takes off.[21]

Pakistan almost certainly has a handful of plutonium-based warheads whose smaller weight makes them more suitable for delivery by missiles over longer ranges. Plutonium-rich spent reactor fuel was first produced by the un-safeguarded 50 MW (thermal) reactor in Khushab, which has been functioning since 1998. It produces an estimated 10 kg/year of plutonium, which is roughly two-bombs-worth. Satellite imagery in 2007 showed that there were two similar units that are currently under construction, with the latest unit's construction having been activated in 2007.[22] In 2011, new satellite images showed that a fourth Khushab reactor was under construction.[23] An assessment of fissile stocks in South Asia has been attempted using publicly available information.[24]

The extraction of plutonium from spent fuel (reprocessing) is a difficult and dangerous chemical process. This is done at the New Labs, a part of PINSTECH (Pakistan Institute of Nuclear Science & Technology) near Islamabad, and now possibly at the Chashma nuclear complex too. Earlier, defense analysts in the U.S. had pointed out that a series of commercial satellite images from February 2002 through September 2006 revealed the construction of what appeared then to be a second plutonium separation plant adjacent to the original one, suggesting that Pakistan was planning on increasing its plutonium stock.

According to Albright and Brannan, Pakistan is doubling the rate of making nuclear weapons:

> Pakistan's construction of these new reactors at the Khushab site will result in a dramatic increase in its plutonium production capability. Combined, the three new reactors will be able to produce enough plutonium for over 12 nuclear weapons per year, depending on the reactors' size and operating efficiencies. This compares with Pakistan's current estimated production of enough weapon-grade uranium and plutonium for about 7–14 weapons per year. These three new reactors will roughly double Pakistan's annual ability to build nuclear weapons to about 19–26 nuclear weapons per year.[25]

The authors further state that:

> In total, through 2010, Pakistan has produced enough weapon-grade uranium and plutonium for roughly 100–170 nuclear weapons. Based on available information, the number of deployed weapons is probably less. Assuming that about 30 per cent of its stock of weapon-grade uranium and plutonium is located in its weapons production pipeline, stored, or otherwise unused in weapons, Pakistan has an estimated total of 70–120 nuclear weapons. It can currently add to that stock at the rate

of about 7–14 warheads per year and that value will go up to 19–26 warheads per year when all four Khushab reactors are operational.

It is a mistake to think that the number of uranium and plutonium warheads actually constructed is equal to the amount of uranium/plutonium available divided by the amount needed per bomb. Even if a country should want to convert its entire stock into weapons, inputs other than fissile material are needed. These include available capacities for converting UF6 gas into metal, explosives, electronics, mechanical component construction, etc. A nuclear weapon has typically about 2000 parts and is a highly complex piece of equipment. In Pakistan, much of the metallization and weapon fabrication work is done in and around the Heavy Mechanical Complex in Taxila, and the adjoining military city of Wah.[26] Many stages of fabrication are involved, the first of which involves conversion of the fissile material in gaseous form into pure metal, then machining it to precise dimensions to make the core. None of this is trivial. But, once a design has been standardized, it becomes easily possible to produce many copies. At the current production rate of a few fissile cores annually, warhead production would most likely follow the same rate and further expansion of warhead production facilities is unlikely to be a major constraint.

Nuclear weapon countries generally go from less powerful to more powerful weapons. Boosted nuclear weapons are the easiest next step. They use the same fissile materials but a few tens of grams of deuterium or tritium gas are inserted inside the bomb.[27] The additional neutrons released result in more complete fission and can increase the explosive power several times over.

Tritium is a by-product of the Khushab reactors. Earlier, the PAEC had attempted to produce it by irradiating lithium.[28] By 1987, the PAEC was able to acquire from West Germany parts for a tritium purification facility. Later, Pakistan attempted to procure from Germany 30 tons of aluminium tubing, used to 'clad lithium for irradiation in a reactor.'[29] In a congressional record of May 1989, Pakistan is said to have 'acquired from West Germany United States-origin tritium—originally destined for H-bombs—as well as tritium recovery equipment. It also obtained a United States-origin high-power laser, the latter as part of a package of equipment for making nuclear fuel'.[30]

Another step towards more powerful bombs is the fabrication of composite cores. This idea is over sixty years old. By combining two materials—a smaller plutonium sphere encased in a shell of highly enriched uranium—Pakistan could make more bombs than if the cores were made of plutonium and uranium separately.

What of the fusion (or hydrogen) bomb? Many times more powerful, this requires a qualitatively different science and needs a plutonium fission bomb to trigger it. India claims to have already developed a fusion weapon—one of the devices tested on 11 May 1998 was announced to be of this type. There is little doubt that Pakistan is seeking to make such a weapon. A plasma physics group in the PAEC, established over twenty years ago, has long looked into fusion weapon matters. The current status of its efforts is unknown, but there appears to have been little progress.

MISSILE CAPABILITY

The groundwork for Pakistan's missile program was laid in the early 1960s with the launch of the *Rahbar*-1 and *Rahbar*-2 weather sounding rockets from Sonmiani beach near Karachi, a project assisted by the United States after it had been approached by Abdus Salam, Pakistan's premier physicist. The first surface-to-surface missile was the *Hatf-1*, with a range of 80 km and a payload of 400 kg. The accuracy was said to be low as they did not have terminal guidance. General Zia-ul-Haq had taken the initiative of setting missile development into motion in response to Indian efforts.[31] A quantum jump in range and accuracy followed the induction of Chinese M-11 missiles, the acquisition of which was denied for a number of years.

The Pakistani missile series can be categorized into two distinct sets. The *Ghauri* missile series, based on a template provided by the North Korean Nodong missile, was developed at the Kahuta Research Laboratories (KRL) while the Shaheen series, based on the Chinese

M-9 and M-11 missiles, was developed at the National Defense Complex (NDC).

Table 1
Pakistani Missile Force

Missile Type	Range (km)	Deployment	Fuel
Abdali (Hatf-2)	180	2012	Solid
Ghaznavi (Hatf-3)	400	2004	Solid
Shaheen-I (Hatf-4)	450	2003	Solid
Ghauri (Hatf-5)	1200	2003	Liquid
Shaheen-II (Hatf-6)	2000	2011	Solid
Babur (Hatf-7)	700	2014	Cruise
Ra'ad (Hatf-8)	350	2014	Cruise
Nasr (Hatf-9)	60	2014	Solid

Data from ISPR bulletins, *Bulletin of the Atomic Scientists* 2011 67: 91–99 by Hans M. Kristensen and Robert S. Norris in: *Pakistan's Nuclear Forces*, *2011*, and Mahmud Ali Durrani, 'Pakistan's Strategic Thinking and the Role of Nuclear Weapons', *Cooperative Monitoring Center Occasional Paper 37*, Sandia National Laboratory.

A 2007 report says that fewer than fifty four-axled Transporter-Erector Launcher (TEL) vehicles, needed for deploying the solid-fuelled *Ghaznavi* (*Hatf-III*) have been sighted.[32] Most are apparently stored at the Sargodha Weapons Storage Complex adjoining the PAF base. The same report refers to roughly fifty four-axled TELs existing for the *Shaheen-I* missile. About fifteen six-axled TELs, suitable for the *Shaheen-II*, have been seen in satellite imagery.

Pakistan is also developing a 500 km range, nuclear-capable, cruise missile named as *Babur*. A Pakistani government supported website[33] states that its design capabilities are comparable to the American BGM-109 Tomahawk cruise missile, and that a 1000 km version is also being developed. The *Babur* is advertised as a 'subsonic, low-level terrain-mapping, terrain-hugging missile that can avoid radar detection and strike with pinpoint accuracy.' Rather than being GPS guided—which depends crucially on the integrity of satellite systems being preserved in times of conflict—it is said to use inertial guidance (and possibly laser gyroscopes). Launched from a TEL, it was first test-flown on 21 March 2006 with President Gen. Pervez Musharraf in the audience. The ISPR also states that, 'Pakistan is looking into modification that will enable the missile to be launched from its F-16s, Mirage and A-5 air platforms and naval platform such as Agosta 90B attack submarines and its Tariq Class frigates.' A test of the *Babur* on 26 July 2007 was declared successful with a range stated to have been enhanced to 700 km.[34] In June 2012 it was described, again in an ISPR release, as having: 'radar avoidance features that can carry both nuclear and conventional warheads and has stealth capabilities. It also incorporates the most modern cruise missile technology of Terrain Contour Matching (TERCOM) and Digital Scene Matching and Area Co-relation (DSMAC), which enhances its precision and effectiveness manifolds.'[35]

A relatively new development, first reported in 2011, is that of low-yield, mobile nuclear delivery systems—called 'shoot and scoot' tactical nuclear weapons. According to an ISPR statement said the *Nasr* (*Hatf-9*) 'Victory' missile could be tipped with 'nuclear warheads of appropriate yield with high accuracy.' It is reportedly a short-range (60 km) surface-to-surface multi-tube ballistic missile system designed for battlefield use.[36]

In July 2011, *The Express Tribune* reported twenty-four more missiles, with ranges between 700–1000 km, would be added to the arsenal. The addition would be the highest production in a single year.[37]

Pakistan has been surprisingly successful in creating a fairly large and diverse intermediate range missile force in a very short time. How is it possible for any developing country with a weak industrial and scientific infrastructure to do so? Making missiles that can fly over long distances is a complex technical task; even today 'rocket science' is sometimes used as a synonym for the most difficult, cutting edge in science.

Missile-making requires acquisition of a broad range of technologies. Some of the key ones are:

- Chemical technology for liquid or solid fuel propellant manufacture, handling, and testing.
- Mechanical technology for rocket motor design, construction, and testing.
- Aerodynamic and structural engineering for design of structures such as missile body, fins, and re-entry cones.
- Special materials manufacturing and moulding capability for high-temperature applications as well as for plastics and polymers. Heat shields for re-entry are essential for protecting the warhead from being rendered useless.
- Computational capability and specialized software for various applications including ballistics, navigation, flow rates, dynamic payload balancing, etc.
- Electronics for missile guidance and control, telemetry, and terminal guidance.

What conclusions can we draw from this apparently phenomenal progress in missile making?

The sophistication of the *Babur's* propulsion system, a lightweight turbo-fan engine, as well as the complex control systems, electronics, sensors, aerodynamics, etc., places it well outside of any comparable achievements by Pakistani industry or other parts of its technological sector. Much the same can be said of the ballistic missiles in the *Hatf* series. There can be no doubt that Pakistan received substantial help from China, as well as components smuggled from Europe. North Korean help is an established fact for the *Ghauri* series, and may well be important for the *Babur* as well.

The details of missile development remain well under wraps but friction between the two main Pakistani organizations, the Kahuta Research Laboratory and the National Defense Complex, which were at one time headed (respectively) by Dr A.Q. Khan and Dr Samar Mubarakmand, has occasionally led each organization to leak information to the press in order to get a greater share of the glory. An Urdu newspaper gave a rare account in 1999 in a planted article entitled: 'How the *Shaheen* was Developed', pours scorn on the KRL group alleging that the *Ghauri* was an imported item whereas the achievements of the NDC group are extolled.[38] Another Pakistani author, evidently commissioned by the PAEC to denigrate A.Q. Khan and the rival KRL organization, wrote the following in a Pakistani defense journal:

> When the PAEC concluded an agreement with China to acquire the solid fuelled M-11 ballistic missiles from China in 1989, A.Q. Khan soon after managed to get the liquid fuelled *Ghauri*, from North Korea, and again hit the public imagination as the man who also gave Pakistan the delivery system for the [B]omb. The fact was that with the foundations of NDC having being laid in 1990, the PAEC was already on its way to start work on the solid fuelled *Shaheen* ballistic missile, before the *Ghauris* or the Taepodongs and Nodongs became operational.'[39]

While Pakistan officially maintains that its missile fleet comes from indigenous development alone, 'indigenous' can be variously defined. In attempting to bring credit to his parent institution, the PAEC, the author accidentally blows away the year-after-year denials by Pakistan of having obtained M-11 missiles from China, as well as of the *Ghauri* being indigenous and not of North Korean pedigree.

In 2009, it became known that Pakistan would collaborate with Selex Galileo of Italy to manufacture unmanned aerial vehicles (UAVs, commonly known as drones) for reconnaissance purposes.[40] The march of technology, spread by the global commercial interests, has profound consequences for the spread of nuclear and missile technologies as well.

Nevertheless, to conclude that Pakistan's missiles are mere foreign imports would be wrong. Pakistan has moved on a two-track missile policy. The first track was acquisition of complete missile systems as CKD (Completely Knocked Down) kits. These are said to have been brought as commercial cargo, mostly by sea but also through the Khunjarab Pass and down the Silk Route from China (this route was closed in 2010 after an earthquake that created the Attabad Lake).

The second track was to understand the systems, then reverse engineer the systems, section by section. Solutions to issues such as vibrations, stability, overheating etc., may be found in specialized textbooks and monographs that are used as texts in graduate level, university level courses taught in many countries including the U.S. and China. Pakistan sends many students to China for studying rocket propulsion and guidance systems. Services from experts in European countries have been purchased for specific tasks such as fin design and theoretical vibration studies.

Once a successful overall system design—say, that of the Tomahawk—is taken as the basic template, the associated sub-systems must be built or acquired. System integration is an exacting requirement and good engineering expertise is essential, but the design challenges are well understood. For designers and manufacturers in advanced, as well as developing countries, the modular nature of modern technology allows for separate units to be transported and then joined together to form highly complex and effective systems. Component level design is no longer essential—the availability of ballistic missile technology, complete sub-systems, navigational gyroscopes and GPS equipment, and powerful computers has allowed many third world countries, including Pakistan and India, to leapfrog across major developmental issues. Systems engineering—which deals with how units behave after being assembled is important, and it is of less importance to know the principle by which individual elements work.

Consider, for example, that 30–40 years ago an electronics engineer working on a missile guidance system had to spend years learning how to design extremely intricate circuits using transistors, capacitors, and other components. But now the engineer only needs to be able to follow the manufacturer's instructions for programming a tiny microprocessor chip, available from almost any commercial electronics supplier. Modular technology applies also to rocketry, including engine design and aerodynamic construction. Computer controlled NC machines have made reverse engineering of mechanical parts easy. In this way even North Korea has been able to create rather advanced missile programs.

Missile development is now part of a burgeoning, increasingly export-oriented, Pakistani arms industry that turns out a large range of weapons: from grenades to tanks, night vision devices to laser guided weapons, and small submarines to training aircraft. Dozens of industrial sized units in and around the cities of Taxila and Wah, with subsidiaries elsewhere in the Islamabad–Rawalpindi region, are producing armaments worth hundreds of millions of dollars with export earnings of roughly 300 million dollars yearly in 2008.[41] Much of the production is under license from foreign countries, some from CKD kits, and most machinery for the arms factories is imported from the West or China.

AIRCRAFT CAPABILITY

Fighter-bomber aircraft were once Pakistan's preferred means of delivering nuclear weapons to India, but they have certain definite limitations. First, their ranges do not permit many parts of India to be covered. Moreover, they would have to run the gauntlet of an increasingly sophisticated Indian air-defense system. Nevertheless, they have the distinct advantage of being reliable, recallable, and reusable.

Pakistan had a deliverable nuclear weapon by 1987, and plans for aircraft delivery long preceded those for missile delivery. According to an officially inspired account, during the 1983–1990 period, the Wah Group [of the PAEC] went on to design and develop an atomic bomb small enough to be carried on the wing of a small fighter such as the F-16. It worked alongside the PAF to evolve and perfect delivery techniques of the nuclear bomb including 'conventional free-fall', 'loft bombing', 'toss bombing' and 'low-level lay-down' attack techniques using combat aircraft. Today, the PAF has perfected all four techniques of nuclear weapons delivery using F-16 and Mirage-V combat aircraft indigenously configured to carry nuclear weapons.[42]

The first F-16's purchased by Pakistan from the U.S. in 1981 arrived in 1983. They were intended to protect KRL, the uranium enrichment facility, as well as to mount retaliatory attacks on Indian nuclear facilities.[43] The U.S. had agreed to the sale of forty aircraft, requested by General Zia-ul-Haq. Pakistan was then a close U.S. ally, fighting against the Soviets in Afghanistan. Another sixty aircraft were ordered in 1989 and paid for but were embargoed; Pakistan's utility as an ally had come to an end.

Pakistan started receiving the first of a batch of F-16 C/D block 50/52 fighter aircraft in July 2007, the most modern version then flown by the U.S. Air Force.[44] It also received assistance for modernizing the existing F-16 fleet to the same standard. F-16s are still said to be the mainstay for aerial delivery up to a range of about 1600 km, but two squadrons of A-5 Chinese built fighter-bombers are also suitable vehicles. There is, however, a caveat that has been added by the United States: the F-16's sold under this deal will be specifically disallowed from carrying nuclear weapons. According to a U.S. official, if Pakistan tried to do so then, 'we have this extraordinary security plan with United States personnel, we have monitoring, we have leverage to convince them not to do this.'[45] The modernized F-16's, however, were presumably unaffected by this restriction.

With the expansion of the army-controlled mobile missile force, demands came from the air force for expansion of its capability. Chief of Air Staff, Air Chief Marshal Tanvir Mehmood Ahmed, announced in March 2009 that $9 billion would be spent on upgrading its 'nuclear status.'[46] What this meant, however, was unclear. Investing in aircraft is no longer an efficient way of increasing nuclear offensive forces.

Today, Pakistan Air Force's technical capabilities remain rather limited and centre around aircraft maintenance. The largest units are the Mirage and F-6 rebuilding factories, an avionics and radar maintenance factory at Kamra, and a factory for manufacturing small training aircraft. There is an Air Weapons Complex located near Wah that manufactures a variety of air-delivered weapons. The JF-17

Thunder, of which 150 will eventually be inducted and become the air force's mainstay, is formally a joint China–Pakistan venture but Pakistani technical input into its design is said to be small so far.

In 2009 PAF air chief stated that an Airborne Warning and Control System (AWACS) was being obtained from Sweden and China, and agreements had been reached with the U.S. to provide electronic warfare system, smart bombs and long-range missile system. He said air-to-air refuelers were being modified. The PAF had almost 550 aircraft, including helicopters and transport aircraft. The number of fighter planes was around 350, he added. At the moment, he said, there were 46 F-16 aircraft in the PAF, including 14 F-16's obtained from the U.S. 'almost free of cost.'[47]

SKILLS: A CRITICAL CONSTRAINT

It would be too easy to ascribe Pakistan's success in bomb and missile-making to merely having allocated a large enough amount of money and resources. However, much wealthier Middle Eastern countries—Iraq, Saudi Arabia and Iran in particular—have been less successful. The difference comes from the few hundred scientists and engineers working under the direction of effective managers, an effective international buying network, as well as the strong will to do it all. Much of the work was reverse engineering, and there are no original applications, devices, or processes of commercial value that have been claimed. Nonetheless, Pakistani weaponeers understood developments in the literature and industry in sufficient detail and with clarity. Most were trained almost entirely in the U.S., Canada, and Britain under a program initiated in the early 1960s by the Pakistan Atomic Energy Commission. By now, many have retired, or are close to retirement.

The burgeoning demand from the principal defense R&D organizations PAEC, NDC, and KRL has resulted in a skill deficit that is perhaps the most serious constraint in the further development of Pakistan's nuclear and missile programs. Public universities are in poor shape, and their graduates are generally ill equipped to understand modern engineering and technical problems. Manpower is being drawn principally from:

Engineering institutes run by the defense organizations. Examples include the Pakistan Institute of Engineering and Applied Sciences (PIEAS), as well as the Centre for Nuclear Studies (CNS). Located on the premises of the Pakistan Institute of Nuclear Science and Technology (PINSTECH) near Islamabad, these institutes offer graduate studies in nuclear engineering, chemical and materials engineering, process engineering, systems engineering, electrical engineering, mechanical engineering, applied mathematics, information technology, etc. The NDC is also in the process of creating various institutes and centres at the Quaid-e-Azam University campus.

- A handful of engineering colleges of relatively better quality such as the army-run National University of Science and Technology (NUST), Ghulam Ishaq Khan Institute of Engineering Sciences and Technology (GIKI), University of Engineering Technology (UET), etc.
- Training of Pakistani missile and weapon designers in Chinese universities and institutes where they undergo short, highly focused, courses on rocket dynamics, navigational techniques, telemetry, etc. These are offered only to employees of government organizations and not general members of the Pakistani public.
- Using the 12-fold increase in its budget over the past five years, the Higher Education Commission of the Government of Pakistan has awarded a number of scholarships to Pakistanis for studying in Europe, Australia, and the United States. Among the beneficiaries are the employees, or former employees, of various defense organizations.
- Academics and engineers in advanced countries can occasionally be interested into solving difficult technical problems for a fee. This follows the widespread global problem of outsourcing technical problems.

- Through better pay and living conditions, the Pakistani weapons complex has managed to get the pick of the crop. But their small number, and the lack of a strict meritocratic system that can get the most out of them, means that skill shortage is likely to remain a serious constraint.

HOW MUCH DO NUKES COST?

The secrecy that surrounds any emerging nuclear program in any country means that, at best, there can only be guess-estimates of the cost involved. Even if items could be freely purchased in the open international market, a country that seeks nuclear weapons would have to put in billions of dollars. But for a program that must be kept under wraps from international watchdogs, one can imagine that the cost would be many times higher. Because imported items are on a list that is carefully watched, circuitous routes must to be found. This entails the use of many middlemen, each with small or large commissions, as well as vendors jacking up their rates.

Neither Pakistan nor India have ever declared their nuclear weapons budgets, treating them as high-level secrets. In fact, an undeclared reason for the Pakistan Army's objection to the Kerry-Lugar Bill, which would have resulted in $1.5bn annually in civilian aid, was its insistence upon financial transparency of the economy. This would have made it easier for outsiders to estimate Pakistan's nuclear budget. The KL program never fully took off.

It has therefore been left up to outsiders to make educated guesses. One such guess is contained in the following table. Figures are in billions of U.S. dollars. Core costs refer to researching, developing, procuring, operating, maintaining, and upgrading the nuclear arsenal (weapons and their delivery vehicles) and its key nuclear command-control-communications and early warning.

Table 2
Total Military and Nuclear Weapons Spending 2010–2011

	Total Military Spending*	Nuclear Weapons		Nuclear Weapons	
		Core Cost	Full Cost	Core Cost	Full Cost
US	687	30.9	55.6	34	61.3
Russia	53–86	6.8	9.7	9.8	14.8
China	129	5.7	6.8	6.4	7.6
France	61	4.6	5.9	4.7	6.0
United Kingdom	57	3.5	4.5	4.5	5.5
India	35	3.4	4.1	3.8	4.9
Israel	13	1.5	1.9	1.5	1.9
Pakistan	7.9	.8	1.8	1.8	2.2
North Korea	8.8	.5	.7	.5	.7
Total:	1052–1085	57.7	91.0	67	104.9

From Bruce G. Blair, Global Zero Technical Report, June 2011

Another estimate, with similar assumptions, arrives at a similar conclusion: Assuming that Pakistan spends on the order of 0.5 per cent of GDP on its nuclear weapons, and using purchasing power parity rather than market exchange rates to convert Pakistani rupees to US dollar equivalents, suggests that in 2009 nuclear weapons program spending amounted to about $2.2 billion a year (the GDP was about $441 billion in purchasing power parity, and $162 billion in nominal terms). For 2011, the nominal GDP was $211 billion, about $484 billion in purchasing power.[48]

FUTURE DIRECTIONS

Looking at the next 5–10 years, one can make reasonable guesses for where Pakistani nuclear forces are likely to be, and the direction of its nuclear policy.

Unless a global fissile material cut-off is somehow agreed upon and implemented, Pakistani production of fissile materials and bombs, as well as intermediate-range ballistic missiles, will continue at the maximum possible rate permitted by technological and resource limitations. A shift towards smaller plutonium weapons, or composite warheads, will accelerate as all Khushab military reactors come on line. The warhead design for the *Nasr* missile suggests that small boosted devices may have been perfected.

The increasing number of warheads will demand an increase in the number of delivery vehicles. In spite of the substantial induction of JF-17 aircraft, as well as newly purchased F-16's, missiles will steadily replace aircraft as delivery vehicles for nuclear weapons. Flight tests and command post exercises will continue to be periodically conducted. Although Pakistan will make efforts to match India's efforts in using outer space for reconnaissance and early-warning systems, it will not be able to do so. An attempt to match India's *Agni-V* ICBM, successfully tested in 2012, is unlikely. But if India is successful in acquiring and installing an anti-ballistic missile system, MIRV, or in deploying submarine launched nuclear-tipped missiles, Pakistan will counter by lowering the strike-threshold and wider dispersion of its mobile launchers, as well as employing decoys and moving towards SLBMs (Submarine-Launched Ballistic Missile).

In the past, Pakistan had felt that hitching its nuclear policy to India's would deflect criticism. The world would understand that its nuclear program was no more than a reaction to a larger, hostile, neighbour's rapid armament. But the 'de-hyphenation' of Pakistan from India—a word that gained particular currency after the visit to India and Pakistan by President George W. Bush in 2006—ultimately drove Pakistan in a different direction; its nuclear policy would henceforth be more than a mirror image of India's.

As for the immediate future: unless India resumes nuclear testing, Pakistan is unlikely to test further. There is little chance that Pakistan will agree to the Fissile Material Cut-off Treaty or to on-site inspections for verification purposes. India will drive the arms race and Pakistan will follow.

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