CHAPTER 8

SECURITY ISSUES RELATED TO PAKISTAN'S FUTURE NUCLEAR POWER PROGRAM

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INTRODUCTION

This chapter deals with the prospects for the expansion of the current Pakistani nuclear power program, and the dangers to national safety and security such expansion entails due to rapid expansion, and the potential military or terrorist attacks against future nuclear power plants. In terms of organization, this chapter is divided into two parts. The first part, including the front two sections, summarizes the current status of the Pakistani nuclear power program, and the prospects for its expansion. The second part deals with the nuclear safety risks that the expansion of the Pakistani nuclear power program might entail, and the security risks related to military or terrorist attacks against nuclear power stations. A detailed conclusions section completes the presentation.

It is concluded here that Pakistan has maintained its currently small nuclear power program in a safe mode, though plant performance records are mediocre, given the limited integration of Pakistani plants into the global nuclear industry. That Pakistan provides many of the requisite plant maintenance and upgrade capabilities from its own resources attests to the potential for improved operations if Pakistan's nonproliferation position could be resolved. Future expansion of the Pakistani program on the scale projected by the government depends on changes in Pakistan's nonproliferation stance that might be related to resolution of the proposed U.S.-India nuclear cooperation agreement. A similar agreement between Pakistan and China, if possible, might allow significant expansion of the Pakistani nuclear program. It is further concluded here that rapid expansion of the installed nuclear capacity might strain the regulatory agencies' capability to supervise safe construction and operation of the prospective new nuclear power stations. Fast-rate capacity growth might strain Pakistan's ability to train adequate numbers of station operating staffs, support infrastructure, and regulatory manpower. The combined effects of the above could lead to safety problems related to plant operations and supervision by poorly trained personnel with potentially severe consequences.

We make the point here that the overall security situation in Pakistan is unstable, with large numbers of terrorist groups allowed to operate within the country, with an armed insurrection ongoing in Balochistan, and with the government's loss of control of several provinces to the Taliban and other Islamic and Arabic terror organizations. This generally unstable security situation is not conducive to stable long-term expansion of nuclear power capacity. An immediate problem may be the difficulty of security screening of all prospective nuclear stations and infrastructure employees, with the distinct possibility of terror supporters gaining access to power stations and providing insider support to putative terrorist attacks. Large multiunit nuclear power stations that likely will be constructed if the nuclear expansion plan is implemented would become vulnerable to terrorist attacks or attempted takeovers all supported by potential inside collaborators. Terrorist attacks against nuclear power stations could be motivated by three factors: (1) the desire to obtain radioactive or fissile materials for the construction of radioactivity dispersion devices or nuclear weapons; (2) the intent to create significant damage to the station, nearby population, the environment, and the country as a whole as revenge for some government actions inimical to terrorist interests; or (3) the desire to force the government to accede to some terrorists demands and modify its policies accordingly. In similar fashion, military action against nuclear power stations can not be ruled out, motivated possibly by the intent to change or reverse government decisions and policies to respond to military demands. Since the military already controls security at all nuclear facilities in Pakistan, military takeover of future nuclear power stations is that much simplified. We conclude here that installing large multiunit nuclear power stations is in the economic interest of any country, like Pakistan, projecting large scale nuclear capacity growth. However, given the less than stable situation in Pakistan such stations are vulnerable to future security threats against the government. Both economic and security trade-offs should be evaluated when considering large scale nuclear capacity expansion in Pakistan's situation.

CURRENT STATUS AND PERFORMANCE OF THE PAKISTANI NUCLEAR POWER PROGRAM

Introduction.

The current status of the Pakistani nuclear power program is reviewed before the prospects for further expansion and the problem this expansion might entail are addressed. Discussion is limited to the commercial nuclear power plants operated, under construction, or planned in Pakistan. The Pakistani nuclear weapons and fuel cycle programs, though indirectly affecting the civilian program as discussed below, are outside the scope of this review. It is important to understand the current small size and limited capabilities of the Pakistani nuclear power program so the multifold increase in capacity planned for it within a relatively short time span can be appreciated. Such rapid expansion will create safety and security vulnerabilities which will be discussed later. It is concluded that the Pakistani plants' performance has been below world standards, caused by the limited contacts established with the global nuclear power industry, given Pakistan's refusal to join the nonproliferation treaty regime. Yet the fact that Pakistan has operated its existing plants safely, and gained a degree of independence in providing plant services, attests to the inherently good capabilities of Pakistan's nuclear plants' personnel and to the potential for enhanced operations if improved relations with the world nuclear power community could evolve.

Current Status.

The current Pakistani nuclear power program is rather modest and consists of two operating nuclear power plants and one under construction. The total installed nuclear capacity is 462 MWe (gross) or 425 MWe (net). The reactor under construction has a capacity of 325 MWe (Gross) or 300 MWe (net).[1] Nuclear capacity represents but 2.4 percent of the total installed capacity of 19,252 MWe in Pakistan by June 30, 2004.[2] Nuclear generation in Pakistan in 2004 was 1.93 TW-Hr, or 2.4 percent of total generation.[3] Thus nuclear contribution to current Pakistani total electricity supply is limited. In comparison, 50.5 percent of total electricity generation in 2004 was produced by fossil thermal power plants, with hydroelectric plants providing 22.4 percent of total generation. The Pakistan Atomic Energy Commission (PAEC) operates all Pakistani nuclear power plants, and the Pakistan Nuclear Regulatory Agency (PNRA)[4] performs nuclear safety regulation. Pakistan shares information with and obtains technical assistance from the CANDU Operators Group (COG), and the World Association of Nuclear Plant Operators (WANO).[5]

Pakistan is not a signatory to the Nuclear Nonproliferation Treaty (NPT). All commercial nuclear power plants are, however, operated under IAEA Safeguards.[6] The Canadian origin KANUPP reactor is safeguarded under INFCIRC/135 of October 1969, and the Chinese origin CHASNUPP is safeguarded based on INFCIRC/418 of February 1993. Pakistan did not sign and did not ratify the IAEA proposed Additional Protocol to its safeguards agreements.[7] Pakistan did sign and ratify the IAEA Convention on Physical Protection of Nuclear Material (CPPNM), which entered into force on October 2000. Pakistan did sign several other conventions with the IAEA;[8] however, it is not a member to the Vienna Convention on Civil Liability for Nuclear Damage.

Pakistan is not a member of the Zangger Committee or the Nuclear Suppliers Group (NSG) and does not abide by the nuclear export guidelines issued by these two organizations. Pakistan has, however, recently held discussions with the NSG aimed at harmonizing its export control regulations with the requirements of the NSG.[9] Given the past activities of the A.Q. Khan's network,[10] which are outside the scope of this chapter, this could well be viewed as "locking the barn door after the horses ran out" and is probably aimed at preparing groundwork for a future nuclear deal with the NSG including measures similar to those incorporated in the U.S.-India Nuclear Agreement,[11] as discussed later. Pakistan participates in the activities of the United Nations Security Council (UNSC) Resolution 1540 Committee, and has submitted a report to the Committee as well as provided later detailed answers to the additional questionnaire.[12]

A listing of plant data related to the construction and operation of the Pakistani nuclear power plants is provided in Table 1 below.[13] A map of Pakistan indicating the location of nuclear power plants as well as nuclear military sites is shown in Map 1.[14] A similar Pakistani map showing the location of nuclear plants and fuel cycle facilities is shown in Map 2.[15]

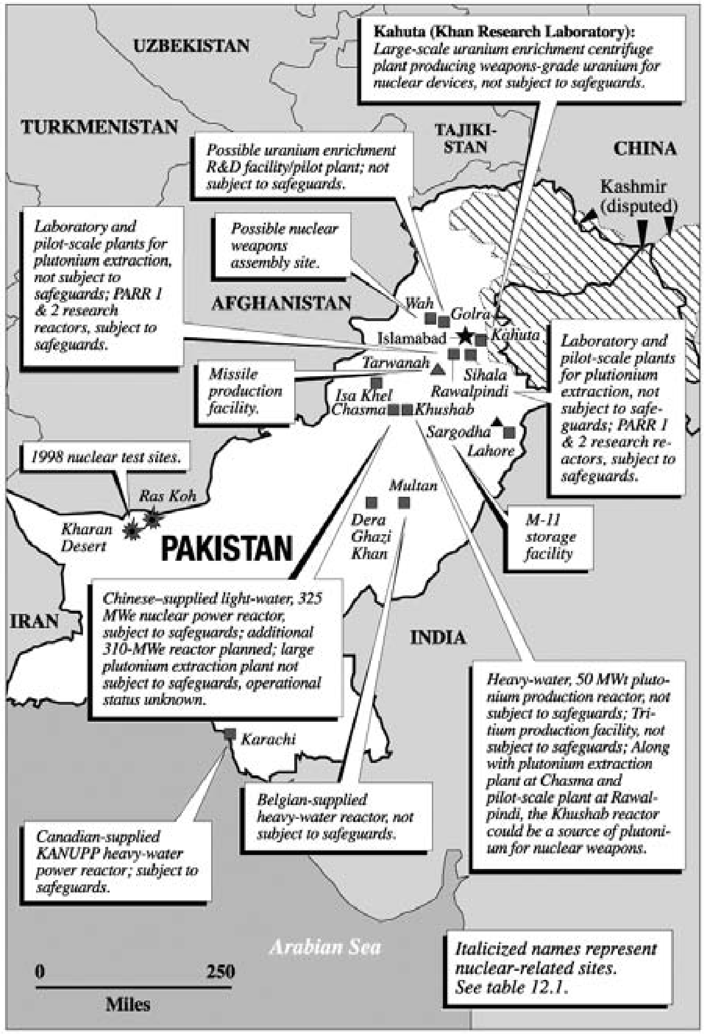
Station	KANUPP	CHASNUPP 1	CHASNUPP 2
Type	PHWR	PWR	PWR
Gross Capacity	137	325	325
Operator	PAEC	PAEC	PAEC
Status	Operational	Operational	Contract signed
Reactor Supplier	CGE	CNNC	CNNC
Construction Date	August 1, 1966	August 1, 1993	April 8, 2005
Criticality Date	August 1, 1971	May 3, 2000	
Grid Connection Date	October 18, 1971	June 13, 2000	~ 2011
Commercial Operation Date	December 7, 1972	September 15, 2000	
Shutdown Date	~2012		

Source: PAEC

Table 1. Current Pakistani Nuclear Power Plants Data.

Map 1. Nuclear Power Plants Locations in Pakistan.

The oldest Pakistani nuclear power plant is the Karachi Nuclear Power Plant (KANUPP), located at Paradise point, 15 miles west of Karachi on the Arabian Sea. A view of KANUPP is shown in Figure 1. KANUPP is a 125 MWe (net) CANDU type natural Uranium fueled and heavy water (Deuterium) cooled and moderated reactor. KANUPP was obtained from Canadian General Electric (CGE) in 1965, and the plant reached commercial operation in 1972. KANUPP and its sister plants in India, Rawatbhata 1 and 2, were based on the Canadian design for the Douglas Point early CANDU plant, which was shut down in 1985.[16] All contacts with the Canadian suppliers were cut off in 1975 when it became clear that Pakistan would not



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Map 2. Nuclear Power Plants and Fuel Cycle Facilities in Pakistan.

become a signatory to the NPT. This required PAEC to undertake an extensive self-reliance program regarding plant operations, maintenance, and capital improvements. PAEC reached domestic capability

Figure 1. The Karachi Nuclear Power Plant (KANUPP).

in CANDU fuel assemblies manufacture by 1980. Following the Three Mile Island accident, Pakistan was accepted into the COG and WANO, and received additional technical assistance and performance assessment from the IAEA. Following 1991, PAEC has embarked on a life extension program referred to as Balancing Modernization and Rehabilitation (BMR) which involves upgrading of the plant's instrumentation and control (I&C) system and replacement of its computer equipment. The BMR program also calls for upgrading balance of plant (BOP) equipment as well as some nuclear island (NI) equipment. With these modifications, plant lifetime is estimated at 40 years, i.e., extended until 2012.[17]

The second nuclear power plant installed and commercially operated in Pakistan is the Chasma Nuclear Power Plant—Unit 1 of 300 MWe (net) capacity, located in the Punjab Province, near Chasma Barrage on the west side of the Indus river. The plant was purchased from China National Nuclear Corporation (CNNC), the main nuclear power corporation in China, and represents the first case of South-South nuclear power plant technology transfer. The design of the CHASNUPP-1 unit is based on the Chinese Qinshan Phase I nuclear power plant, the first indigenously designed and built nuclear power plant in China. The Qinshan Phase I design is the current nuclear plant export model of China and has also been offered to Iran (cancelled in 1997 under U.S. pressure), and to all other countries interested in small capacity nuclear plants provided by a Third World nuclear supplier. Even though the reactor design is of Chinese origin, Mitsubishi Heavy Industry (MHI) produced the pressure vessel and the two primary pumps were manufactured in Germany.[18] The CHASNUPP-1 nuclear plant is a two-loop pressurized water reactor (PWR), fueled with 3.4 percent enriched Uranium Oxide fuel provided by China. CHASNUPP-1 represents the second unit worldwide based on the Qinshan Phase I design and the first Chinese nuclear power plant export. As such, this is a prototype operation to both China and Pakistan. No information on possible spent fuel return to China is available, and wet pool storage of spent fuel at the reactor site is assumed. No information on possible reprocessing of spent fuel for military purposes, particularly from KANUPP, is available. The construction of the CHASNUPP-1 unit was started in 1992, and commercial operation was attained in 2000. Since then the plant has completed five annual operating cycles with an improving performance trend.[19]

The second unit of the Chasma nuclear power plant (CHASNUPP-2) will also be supplied by CNNC and is a 300 MWe PWR design similar to the Qinshan Phase I plant operating in China, and a replicate of the CHASNUPP-1 unit operating on site. The total investment in the new unit is estimated at 860 Million Dollars,[20] and a sum of 350 million dollars is financed by China, $200 M through concessionary loans and $150 M through preferential supplier credits provided by the Exim Bank of China.[21] Site construction work started in April 2005 and commercial operation is expected by 2011. China became a member of the NSG in June 2004,[22] and as a member is forbidden by NSG Guidelines from supplying nuclear equipment to countries that did not sign the NPT and did not accept full scope safeguards. However China claims that its contract negotiations with Pakistan regarding CHASNUPP-2 construction have been ongoing even before its accession to NSG membership, and are thus "grandfathered" from its NSG obligations.

The Chasma nuclear site includes also a reprocessing plant, based on a French design supplied by the Saint Gobain Corporation. With the cessation of French nuclear assistance to Pakistan in 1975, Pakistan has completed the construction of the plant by itself and PAEC operates it outside of the safeguards regime in support of its nuclear military program.[23] In close proximity to the Chasma site is the Khushab Plutonium production reactor provided by China.[24] Khushab is a 50 MW (Th) natural Uranium fueled, heavy waster moderated reactor operated by PAEC as a part of the Pakistan nuclear weapons program. Other military program facilities are indicated in Map 1. Several research reactors also operate in Pakistan, however they are outside the scope of this chapter.

Operating Record of Pakistani Nuclear Power Plants.

It is important to review the operating record of the current Pakistani nuclear power program in order to assess how future nuclear plants will be operated given the fast expansion plan proposed by the government. As discussed next, the current operating record is below world standards, even though the inherent capability for improved performance is there. The concern is that given the fast growth rate projected, the potential for better performance might not be realized for some time. Conversely, the Program might be vulnerable to safety and security problems brought about by inexperienced staffs or by terrorist sympathizers who managed to foil the clearance system and act as inside collaborators.

The energy availability factors (energy produced after all losses are deducted divided by total energy produced) which are related to the capacity factors (net energy produced divided by the total energy that could have been produced had the plant operated at full capacity all the time) are computed by the IAEA and reported on an annual and cumulative basis in the Power Reactor Information System (PRIS) database for each commercial nuclear power plant operating in IAEA member countries.[25] The history of the energy availability factors over the lifetime of the KANUPP reactor is reported in Table 2 below, and for the CHASNUPP-1 reactor in Table 3.[26]

Inspection of the KANUPP performance data in Table 2 indicates a mediocre plant record with a lifetime energy availability record of less than 28 percent. This is particularly low for a CANDU type reactor, which

Year	Energy (GWe.h)	Capacity (MWe)	Energy Availability Factor (%) Annual	Cumulative
1971	3	128	77.27	
1972	232.7	137	19.3	
1973	394.8	126	35.6	35.6
1974	583.9	126	52.75	44.18
1975	494.9	126	44.83	44.39
1976	487.3	137	40.49	43.35
1977	339.4	126	30.74	40.88
1978	228.4	125	20.88	37.62
1979	29.6	125	2.7	32.72
1980	67.9	125	6.17	29.45
1981	192.2	125	17.55	28.14
1982	70.9	125	6.48	26.01
1983	194	125	17.7	25.26
1984	290.65	137	24.9	25.23
1985	261.96	137	21.83	24.95
1986	476.22	125	43.49	26.24
1987	274.77	125	25.09	26.17
1988	171.41	125	15.6	25.52
1989	60.86	125	5.56	24.37
1990	375.906	125	34.33	24.91
1991	370.3	125	33.82	25.37
1992	499.74	125	45.51	26.36
1993	369.6	125	33.75	26.71
1994	523.64	125	47.82	27.66
1995	461.04	125	42.1	28.28
1996	310.86	125	28.31	28.28
1997	386.12	125	35.26	28.55
1998	353.35	125	29.74	28.6
1999	68.99	125	11.93	27.99
2000	368.31	125	33.54	28.18
2001	399.46	125	36.48	28.47
2002	444.02	125	40.55	28.87
2003	0	125		27.94
2004	183	125	24.71	27.84

Table 2. Annual Performance Data for the KANUPP Reactor.

Year	Energy (GWe.h)	Capacity (MWe)	Energy Availability Factor (%) Annual	Cumulative
2000	529.15	300	72.19	
2001	1581.75	300	60.06	60.06
2002	1356	300	52.25	56.16
2003	1809.8	300	68.85	60.39
2004	1750.71	300	66.35	61.88

Table 3. Annual Performance Data for the CHASNUPP-1 Reactor.

operates on online refueling principles and is thus expected to demonstrate high availability and capacity factors. In fact, KANUPP performance is lower than even the oldest CANDU reactors operated in Canada and elsewhere except for the Rawatbhata reactors in

India. KANUPP represents the oldest CANDU model still refurbished and in commercial operation in the world today. Most other similar model CANDU reactors have already ceased operation and have shut down. That KANUPP still operates is a testament to the resourcefulness and determination of the Pakistani nuclear engineers. The operational history of KANUPP is the story of Pakistan's nonproliferation policy and external relations.

As seen in Table 2, the plant started commercial operation and after a slow start performance improvements were recorded until 1975, the year Canada cut off technical support due to Pakistan's refusal to sign the NPT. The KANUPP engineers were on their own with no fresh fuel assembly supplies, replacement parts, training or technical support from Canada. Performance deteriorated significantly and revived only in the mid-1980s when the Pakistanis learned to manufacture their own fuel assemblies and developed some domestic plant maintenance and component replacement capabilities. Since then the plant operated at varying performance levels never exceeding 48 percent and was down for different Pakistani initiated refurbishment campaigns. Performance, even at these low levels, has improved following the reestablishment of technical exchanges with the COG and with WANO. By that time the plant was getting older and its improving performance trend was overtaken by the need for further maintenance and modifications (M&M). The overall result is that of mediocre performance quite lower than other CANDU reactors operated elsewhere.

Another relevant element is the low burnup levels achievable at CANDU plants. The KANUPP reactor was designed for an average (over the core) assembly burnup of 8,650 MW (th) D/MTU and for cycle length (period between refuelings) of 12 months.[27] At this low burnup level the percent fissile content of the discharged plutonium (Pu-239 + Pu-241) is estimated in the low 80 percent, almost weapons grade. If fuel assemblies were discharged annually regardless of the low achieved capacity factors, the realized fuel burnup would have been lower and the fissile content of the discharged plutonium would be higher, and close to weapons grade quality. It is also known that natural uranium fueled heavy water moderated reactors (like the CANDU models) are copious producers of plutonium in the discharged fuel assemblies ~ 360 Kg Fissile Pu/GWe/Year, according to the DOE Nonproliferation Alternative System Assessment Program (NASAP) report.[28]

Thus, assuming annual refuelings, the KANUPP reactor could have produced significant amounts of weapons grade (or close to weapons grade) plutonium in its discharged fuel assemblies. The KANUPP reactor, including its spent fuel pool, is operated under IAEA safeguards. However, given the relatively mild application of safeguards by the IAEA prior to the early 1990s when the Iraqi nuclear weapons program was discovered, the Pakistanis might have been able to divert some fuel assemblies to their unsafeguarded program. This is only a speculation, based on the fact that the KANUPP spent fuel pool might contain, by now, significant amounts of high grade plutonium, thus offering a tempting target.

Inspection of the CHASNUPP-1 performance data shown in Table 3 indicates significantly higher energy availability levels, in the range of 60 percent plus as compared with the lower performance record of the KANUPP reactor discussed above. Evidently, the more modern and simpler PWR design and possibly ongoing help from CNNC which may have wanted their first export project be a successful one, might have contributed to the improved plant performance. CHASNUPP-1 performance declined during the first three annual operating cycles until the plant "settled down," and then the availability factor markedly increased over the next two cycles. Yet the fact is that the CHASNUPP-1 performance record lags the record of the Qinshan Phase I plant—its reference plant—by 10 to 20 annual percentage points over the same operating period. Review of the *Qinshan-I* data in the PRIS database[29] indicates that whereas *Qinshan-I* has a cumulative (lifetime averaged) energy availability factor of close to 80 percent over its first five operating cycles, CHASNUPP-1 has reacted with a cumulative availability factor of 62 percent only (still much better than the 44 percent cumulative availability factor recorded for the KANUPP reactor over its first 5 operating years).

Two general trends can be identified from review of the performance data of the first two Pakistani operating nuclear power plants. First, energy availability factors are lower than those recorded for similar plants located elsewhere, possibly reflecting Pakistan's isolation within the global nuclear community given its nonproliferation stance. Second, valiant attempts have been made by the Pakistanis to improve plant performance, relying mostly on their own limited national resources. The results indicate improving performance records although lower than worldwide figures for similar plants over similar operating periods. Evidently more needs to be done, with significant external inputs to bring Pakistani nuclear plants performance to world-class level and assure long-term safe plant operations. It could well be that with adequate external support (if this were possible) and with the development of additional nuclear infrastructure and technical capabilities within Pakistan, the performance of the Pakistani nuclear plants could reach levels similar to those achieved by other successful Asian nuclear nations like Taiwan or Korea.

Expansion Plans of the Pakistani Nuclear Power Program.

Pakistan's Mid-Term Development Framework of 2005 calls for the installation of an additional 8,500 MWe of nuclear capacity by the year 2030,[30] which will bring the operating capacity by that year to about 8,800 MWe. The first part of this overall program involves a Pakistani request to purchase eight 600 MWe reactors from China with a total program capacity of 4,800 MWe.[31] Pakistan has requested export of the second generation of indigenously designed Chinese nuclear plants based on the Qinshan Phase II, a 2 x 600 MWe station now reaching full commercial operation in the Qinshan site near Shanghai, in Zhejiang Province. The first two 600 MWe units in Pakistan are planned for the KANUPP site near Karachi. It is surmised that one future nuclear station might be located in Balochistan.[32] Should Pakistan manage to import only one 300 MWe unit in the early expansion phase, that unit might be built at the Chasma site as CHASNUPP-3 unit.

A recent report on the status of the Qinshan Phase II program was provided by Kang Rixin, the director General of CNNC.[33] The Qinshan Phase II station includes two units, each one being a two-loop PWR of 650 MWe (gross) or 610 MWe (net).[34] Construction of the first unit on site was started in June 1996 and the plant reached commercial operation in April 2004. Construction of the second unit of Qinshan Phase II was started on April 1997, and commercial operation started in May 2005. CNNC received approval in 2005 to replicate on site the Qinshan Phase II units and these will become the third and fourth identical units on site, referred to as the Qinshan Phase IV project. China plans the Qinshan Phase II units to be the prototypes for all 600 MWe nuclear units of indigenous design which might be built in the future in remote nuclear plant sites in China, or exported to clients like Pakistan. As yet, no reactor of this type has ever been exported outside China.

The Qinshan Phase II plant design was based on Chinese expertise, though with significant French and Japanese contributions. In terms of components manufacture, 55 percent of Qinshan Phase II first unit equipment was of Chinese origin, the rest being imported, mostly from Japan. The localization content of the second unit on site was 60 percent. While China is capable of building the 600 MWe turbine generators used in this station, most of the nuclear island equipment―including the pressure vessel, steam generators, and primary pumps―were manufactured by the Mitsubishi Heavy industry (MHI) Corporation of Japan.[35] China is yet incapable of constructing the main components of the nuclear island of a 600 MWe nuclear unit, let alone larger sized nuclear units. This limits China's ability to export the 600 MWe sized plants since it must obtain the approval of the foreign NI equipment supplier (and its government) for the production of the nuclear components prior to the signing of an export deal with a client country.

Exporting new nuclear power plants to Pakistan (beyond contracts already negotiated) is difficult since most nuclear exporters belong in the NSG, and NSG guidelines prohibit export of nuclear components to countries that did not sign the NPT and signed "full scope" safeguards agreements with the IAEA. In Pakistan's case, all its commercial power plants are under safeguards; however, its military facilities are excluded from the safeguards regime so it does not meet the "full scope" safeguards criterion. Pakistan did not sign the NPT, and furthermore, it might have helped and abetted the proliferation activities of A. Q. Khan and his network,[36] might not have come clean regarding the full extent of Khan's activities, and has prevented independent interrogation of A. Q. Khan by foreign experts (except for limited contacts with the IAEA, and possibly the United States regarding the Iranian and North Korean putative enrichment programs). It is also possible that General Musharraf, while serving as army chief of staff, might have known, if not approved, of Khan's last major proliferation program in Libya. Given this record, it is not clear that even the more lenient NSG members so far as Pakistan is concerned, like China, might be able to bypass the NSG guidelines and export future new nuclear plants to Pakistan. In the case of the Qinshan Phase II plant, export approvals might also need to be obtained from Japan and France, which might not be willing to bend the NSG Guidelines sufficiently on Pakistan's behalf. It might be possible that when China develops independent manufacturing capability for heavy nuclear island components, it might be able to strike specific export deals with Pakistan, unencumbered by other more conservative NSG members. However, that capability does not yet exist in China, and its development might require a gestation period of 10 to 20 years to achieve adequate high quality control in the domestic manufacture of such heavy components. Thus under normal business conditions, the ability of China to export Qinshan Phase II type reactors to a country like Pakistan is not a foregone conclusion.

This situation changed, however, with the signing of the U.S.-India nuclear cooperation agreement in July 2005 and the facilities separation plan of March 2006. Pakistan has demanded a similar deal for itself and has requested comparable nuclear cooperation agreements with the United States,[37] Russia,[38] China, France, Canada, and possibly others. Pakistan's demands for equal treatment with India are based on the fact that all its commercial nuclear plants, unlike India's, have always been under IAEA safeguards. Pakistan further claims that it has put the A. Q. Khan affair behind it, conducted adequate investigation of the affair, punished Khan and his collaborators, strengthened its institutional controls over its entire nuclear complex, and coordinated its export control policies with the NSG[39] as well as with the United Nations (UN) Resolution 1540 Committee.[40] As such, Pakistan views itself as having turned a corner and deserving of a special nuclear cooperation deal similar to that signed between the United States and India. Such an agreement could be signed between Pakistan and the United States (preferably); the United States, Pakistan, and India;[41] Pakistan and China;[42] or Pakistan, China, and any other member of a group of other friendly countries such as Russia, Canada, or France. So far, the United States has refused to consider a nuclear cooperation agreement with Pakistan similar to the India deal. President George W. Bush did not publicly address this issue during his visit to Pakistan in early March

2006, and U.S. Department of Energy (DOE) Secretary Samuel W. Bodman, during his visit to Pakistan on March 13, 2006, refused to discuss nuclear cooperation with Pakistan,[43] limiting his discussions to non-nuclear energy cooperation only. Pakistani contacts on these matters in both Washington and Beijing continue to await the review of the U.S.-India deal by the U.S. Congress and by the NSG. A possible new nuclear sale deal will be discussed during President Musharraf's visit to China in June 2006 to attend the meeting of the Shanghai Cooperation Organization (SCO).

To recapitulate, it seems that Pakistan's strategy is to convince the United States or China (and possibly other interested nuclear supplier countries) to offer it a nuclear deal similar to the agreement between the United States and India, and to have such a deal approved by the NSG. Since in the near-term China cannot manufacture all the nuclear island components of its new 600 MWe plant, it will require the consent of the supporting equipment manufacturers—Japan and France—before it can export the newer Qinshan Phase II plant to Pakistan. Pakistan will keep all its commercial nuclear power plants under IAEA safeguards but retain uninspected control over its military program facilities. Pakistan will also abide by the requirements of UN Security Council Resolution 1540 and harmonize its export control guidelines with the NSG, much like China did prior to accession to full membership. While this is a less than full scope safeguard as required by NSG guidelines, and while Pakistan could not thus sign the IAEA Additional Protocol (which may become an NSG condition of supply in the future), the agreement it *is* willing to sign is more comprehensive than the facilities separation agreement reached between the United States and India.[44]

Assuming the above transpires and Pakistan could import 600 MWe class PWRs from China or eventually larger sized plants from China or other nuclear suppliers such as Canada, Russia, France, and eventually the United States so as to meet its target of 8,500-8,800 MWe installed nuclear capacity by 2030, this will require the identification, characterization, qualification, and regulatory certification of several new nuclear station sites. To estimate the number of sites required, assume that all capacity additions will be provided in terms of 600 MWe units. This implies that about 14 new units will have to be installed, the first two of which are already planned for the KANUPP site near Karachi. We can further assume that Pakistan will build multiunit sites, as Japan, Korea, India, China, and most other Asian nuclear power countries have done. Should Pakistan opt for four unit sites, its planned nuclear construction program will require the opening of three new four-unit station sites. This would be in addition to the two existing power plant sites near Karachi and Chasma.

The number of sites estimated here would increase if not all the proposed sites could accommodate four units or if some of the units ordered are of the 300 MWe size, and would decrease if larger units than 600 MWe could be constructed during the later phases of this nuclear plants expansion program. Considering the difficulties of obtaining approvals for the export of 600 MWe Qinshan Phase II plants from the multiple suppliers and from the NSG, China might revert to providing Pakistan with the 300 MWe Qinshan Phase I reactors that can be manufactured based mostly on China's internal resources only. This might require doubling the number of new sites required, until the issues involved with exporting the larger sized nuclear plants are resolved. Given the landmass of Pakistan, the opening of three new multiunit nuclear sites between now and about the year 2020 (when the last site must be opened) seems achievable.

PROSPECTIVE NUCLEAR STATION SAFETY PROBLEMS

Introduction.

The fast expansion rate proposed for the Pakistani nuclear power plants' capacity from 325 MWe to 8,800 MWe over a 24-year period in a country with limited nuclear industrial infrastructure, may pose some safety risks as discussed below. In turn, these safety issues may also have national security implications, given the volatile security environment in Pakistan and along its borders with its neighboring countries, as discussed in greater detail in the next section. The need to hire and train at a fast rate large numbers of regulators, station staffs, and support personnel creates vulnerabilities for the nuclear program in terms of operation by inexperienced crews and the emergence of terrorist supporters within the system. Such vulnerabilities might lead to safety-related events discussed in this section or to security threats discussed in the next section. It is important to note that safety-related events might cause severe social and economic implications on their own, and might precipitate further national security related actions by the government, or terrorist attacks trying to capitalize on the general unrest created by a safety event. Each one of the safety issues discussed here is of concern, in and of itself. The possible combination of more than one of the factors listed here might prove problematic.

Inadequate Regulatory Oversight.

The nuclear capacity expansion plan proposed for Pakistan might strain the oversight capabilities of the Pakistani nuclear safety regulatory agency─the Pakistani Nuclear Regulatory Agency (PNRA). PNRA might be called upon within a period of less than 20 years to license the construction of 10 to 20 new nuclear units (depending on reactor capacity), i.e., a rate of one new plant license every 1- to 2-year period. This may be a fast rate for an agency that over its existence has licensed no more than two nuclear units (KANUPP having been constructed probably before PNRA was established). Worldwide experience indicates that a new nuclear plant licensing process may require several years─from 2 to 6 years. Thus it is likely that PNRA will have to undertake a parallel licensing process involving more than one unit at a time. This problem might be somewhat ameliorated given the Pakistani intent to standardize new plant purchases, so that the regulators might be familiar with units they may have licensed previously. If Pakistan might have to import several types of reactors from one country, e.g., Chinese 300MWe, 600 MWe, and later 900 MWe sized units, this will increase the strain on PNRA regulators who will have to become familiar with several types of new plants almost at the same time. If more than one supplier country will eventually be able to export nuclear plants to Pakistan─China, Canada, France, Russia or the United States─this will further increase the learning curve required of the PNRA staff.

A new plants construction program requires additional regulatory reviews of new sites qualification and licensing. As discussed above, the Pakistani nuclear plants construction plan might require the licensing of at least three new sites during the next 20 years. While this is a "doable" effort in and of itself, coming on top of the reactor licensing commitments might further strain PNRA resources. Site licensing is a detailed process requiring the review of the site characterization studies and the evaluation of how many units of a particular type the site can accommodate given the reactor and site-specific data. Sites found to have limited capacity potential may require further opening of new sites. Local population density around the sites or political opposition to nuclear plants construction may exacerbate the problem of finding an adequate number of sites along with the regulatory review burden.

Finally, the PNRA will not only have to license new nuclear sites and reactor types, but it must also supervise the safe operation of the nuclear units already installed and operating. As we have seen before, the operating records of the existing Pakistani nuclear units show improving trends over time, but are lower than world standards. This will require continued monitoring of plant operations to assure occupational and public health and safety. In this arena, the independence of the safety regulators from external pressures to increase electricity generation at the expense of safety considerations will be important. As PNRA will constantly be expanding its resources to meet its regulatory obligations, it may well happen that new and yet inexperienced staffs might not be able to well withstand outside pressures to generate, with potentially serious consequences either immediately, or down the line. The history of the regulatory oversight vs. plant operational considerations in the Chernobyl plant is a case in point.

Thus, the overall strain on PNRA resources, having to contend with assuring the safety of operating plants, licensing new sites, and further licensing the construction of new nuclear units, all within a relatively short time of 20+ years may become severe. Given the limited trained manpower resources of Pakistan, even with foreign help, assuring adequate regulatory oversight may be a challenge.

Inadequate Operator Training.

The problems of qualifying trained manpower for nuclear plants operation may be as severe within the PAEC side (the nuclear operator) as they might be within the nuclear regulator (PNRA) side. Nuclear units require operations and maintenance (O&M) staffs estimated in the range of 0.5─1.0 Persons/MWe or even higher ratios (~1.5 Persons/MWe) in the nuclear programs of third-world countries. Thus for 8,800 MWe nuclear expansion program, an operations cadre of 4,400 to 8,800 persons or more may have to be trained and qualified over a 20-year period. On the surface, this seems easy for a country of 150 Million people. Yet most plant staff persons require special training and years of experience. Licensed nuclear plant operators, let alone Senior Reactor Operators and shift supervisors may require even additional years of training. The Koreans, with a larger and more mature nuclear plants program, refer to their licensed plant operators and senior operators as "Gold People" since they are viewed as "worth their weight in gold." The training requirements for plant operators should be considered in conjunction with the need to train nuclear plant regulators for the PNRA, provide trained manpower for the nuclear infrastructure industry supporting PAEC, and provide additional trained manpower for the Pakistani military program and the related nuclear fuel cycle industry. We can assume that the numbers of the additional civilian regulatory and nuclear infrastructure personnel that will have to be trained will about equal the number of nuclear stations personnel. At the outer envelope, this equates to an additional 8,800 persons. Thus the Pakistani training and educational system will have to qualify about 18,000 trained persons over a 20-year period or close to 1,000 persons per year over each of the next 20 years to provide the personnel needs of the expanding nuclear power program. Not all of these persons will have to be trained to the same levels, but all will have to receive basic radiation worker and plant safety training.

The consequences of having less than well-trained staff at an operating nuclear power plant could be significant. Routine plant operations and maintenance activities might suffer delays in identifying and fixing small-scale problems. This could be further exacerbated by the limited availability of industrial infrastructure supporting plant operations in the areas of diagnostics and surveillance. Outage management which requires long planning and preparation might be less than could be achieved in other nuclear programs. That all nuclear plants are operated by a government agency, PAEC, might limit the exposure of plant operations to economic market forces and the discipline of the market. All these factors combined might lead to the low capacity factors and energy availability factors incurred in the nuclear program, as noted above. This low plant availability situation might be tolerable in a 425 MWe program, which provided less than 2.0 percent of national generation. When the installed nuclear capacity might reach 8,800 MWe—close to 20 percent of total capacity and might be expected to provide 20 percent of total generation, low availability factors might be less well-tolerated, and PAEC might be pushed to increase electricity send-out from its generating stations whether the operating staffs are ready or not.

Nuclear plant operation with relatively inexperienced staff might increase the chance of severe nuclear accidents. Nuclear plants are designed with relatively large safety margins, which makes them somewhat forgiving of operational mistakes. However, if an accident precursor event occurs and the operators misread their computer and indicator dials and misdiagnose the significance of the event, they might initiate a wrong corrective action, which might worsen the situation, leading eventually to a full blown nuclear plant accident. The importance of having well-trained and drilled plant operations staff, with continuous on-the-job and simulator trainings, who are steeped in the discipline of following plant procedures and not operating beyond equipment technical specifications, was highlighted in the Three Mile Island and Chernobyl nuclear plant accidents. In both accidents inexperienced staff members either misdiagnosed equipment reading and plant monitoring systems, or willfully ignored operating procedures in order to achieve management-dictated performance goals. While more modern plants have incorporated significant improvements in man-machine interaction, the potential for an inexperienced crewmember making the wrong technical decision thus worsening an evolving accident chain cannot be discounted. This is particularly so when the nuclear capacity expansion plan gets into high gear and new nuclear units are commissioned at relatively high rates which outpace the rate of new operator training and maturation.

Another aspect of operating nuclear plants with less than well-trained staffs may be the lack of adequate response to security emergencies. As will be discussed later, various security emergency scenarios ranging from attempted takeover of the nuclear plant by subnational groups for political purposes to attacks on nuclear stations either to divert nuclear materials or to damage the reactors as an act of revenge for some grievance inflicted (real or imagined), cannot be ruled out in Pakistan's environment. Given such ever-present danger, a less than well-trained nuclear staff, which may not be familiar with plant security and protection procedures, might not be able to withstand a well-motivated attack led by experienced terrorists. In particular, new multiunit stations with relatively new staffs (newly arrived) may be susceptible to insider threats assuming some members of the new staffs might not have been adequately security vetted by the authorities. Even if no insider's threat materializes, it is not clear that a relatively new staff will know how to handle emergency situations caused by multiple explosive laden trucks similar to the (almost successful) Saudi al-Qaeda attack on the oil facilities in Abqaiq, Saudi Arabia, in early 2006.[45] Nor is it clear that a raw staff will know how to handle conflagrations which might ensue should a terrorist group manage to load a plane with explosives and dive it into a nuclear containment structure. This sabotage attack is not completely out of bounds in Pakistan, and newly arrived and less than adequately trained staffs might not be able to respond properly.

Protection of Spent Fuel Storage Pools.

One of the side problems engendered by multiple units sitting in one station is the large amount of spent nuclear fuel that will accumulate in the cooling ponds of all the reactors located on site. A CHASNUPP type reactor discharges on an annual cycle of 11.9 MTHM/ year.[46] The existing two units CHASNUPP station will have, after 5 years of equilibrium fuel cycles operation of both units, about 120 MTHM stored on site. This is not taking into account the early years of operation of CHASNUPP-1 and the first core discharges from both units. Since the station life is expected to be 40 years and since no plans for central storage of spent fuel, fuel reprocessing, or take back of the spent fuel to China were announced, then close to the end of life of the CHASNUPP it will contain on site about 1,000 MTHM of spent fuel. Spent fuel accumulation will double for prospective future four-unit CHASNUPP type stations rather than the two-unit station now being constructed.

More intensive accumulation of spent fuel is expected for future Pakistani stations containing 600 MWe reactors possibly copied from the Chinese Qinshan Phase II design. No data on fuel consumption and discharge from this reactor were yet published; however, the 300 MWe Qinshan Phase I reactor discharges 13.5 MTHM/year.[47] Assuming fuel consumption of a 600 MWe reactor will about double that of a 300 MWe reactor and rounding off for economy of scale, we can estimate that a Qinshan Phase II reactor will consume and discharge annually about 25.0 MTHM/year. Thus, a prospective four-unit Qinshan Phase II station operating in Pakistan, after a future 10-year operation period of all four units, will have accumulated on-site a spent fuel load of about 1,000 MTHM, and this amount will about quadruple towards the end of its life. Much larger spent fuel accumulation could be expected assuming it may be possible to construct CANDU type reactor stations in Pakistan. The plutonium contained in such spent CANDU reactor assemblies will be closer to weapons grade as compared with the higher burnup plutonium discharged from the Chinese PWR stations.

The large accumulation of plutonium containing spent fuel in the future Pakistani nuclear power stations, assuming the nuclear expansion plan is implemented, could act as a magnet for all sorts of terrorist groups or subnational organizations with a grievance against the central Pakistani government. This issue will be discussed in greater detail in the next section. Suffice it to say here that unless plant staffs and their security complements are well-trained, they might not be able to effectively protect their stations from future attacks. It is just possible to assume that due to the multiple units co-location feature planned by PAEC, an external attack has a greater chance of hitting or capturing one part of a station, if not all of it. A subnational group attack against a multiunit station such as truck bomb convoy, commando style land attack, or an airplane attack, even if deflected from one unit, might still succeed against another. Once a hostile force captures one unit in a station or heavily damages a unit, the fight is over and the station is effectively lost, with all the attendant consequences. This is a risk element that should be considered when implementing an extensive nuclear power expansion plan based on multiunit stations in a politically unstable environment. If it will be decided to construct smaller-sized stations due to security considerations as noted above, then a larger number of sites will have to be qualified, licensed, and eventually protected.

Common–Mode Failures and Impacts on Grid Stability.

Multiunit siting carries with it also nuclear safety risks related to common-mode failures and power station impacts on the electric transmission grid. Common-mode failures are events or accidents that affect entire groups of co-located units or similar technology and design units. In the past, the most notorious common-mode failures that have affected entire classes of plants were the need to replace stem generators in PWRs due to stress corrosion cracking in Inconel 600 constructed steam generators; the need to replace PWR reactor vessel heads due to cracking near the control rod penetration tubes; the core shroud corrosion in Boiling Water Reactors (BWRs) that have shut down the entire BWRs fleet of Tokyo Electric Power corporation (TEPCO); the need to retube CANDU reactor pressure tubes due to tube sagging under thermal and radiation induced stresses; and the need to remove tritium from CANDU reactors' heavy water due to increased accumulation of tritium in the heavy water with the attendant radiation risks. During the last year, a new problem has emerged in Westinghouse-designed modern four-loop PWRs constructed by the Commonwealth Edison Corporation of Chicago (CECO, now part of Exelon corporation)—that of tritium leaks from the primary system to local water sources.[48]

Most of the above noted failures have been corrected by the global nuclear industry and remedies were most likely incorporated into the designs of relatively modern plants that might be offered to Pakistan such as the Qinshan Phase II reactor. Yet, the potential for discovering new generic problems can not be discounted as the case of the tritium leaks from the more modern Exelon plants demonstrates. In this regard, we should note that the Qinshan Phase I reactors (one in operation and one being constructed in Pakistan) are based on a 1980s vintage domestic Chinese design which may not incorporate the latest plant design innovations, materials, or modern equipment. This reactor represents the second of its type constructed anywhere and the first Chinese nuclear plant export. The potential for future defects being discovered and potentially leading to the initiation of a nuclear accident chain cannot be discounted given the relatively limited operations experience accumulated. The Qinshan Phase II reactors represent a mix of design data and components supply from China, Japan, and France. There exists even more limited operational experience to indicate that no unforeseen problems will emerge in this complex plant, than the case is with the Qinshan Phase I reactor. These putative problems were hinted at by Indian authors.[49] Thus, the two reactors that are available or proposed to Pakistan might exhibit later in life safety problems that could affect all such plants to be constructed: in the first case due to a relatively older design and in the second case due to design complexity. Should a generic problem occur in a multiunit future Pakistani station, the units might need to be shut down one at a time, or the entire station might need to be shut down to implement the required fix-ups and modifications. Should more than one multiunit station be operational at the time a generic problem is discovered, the impact on PAEC operations and on the entire Pakistani electric grid could be that much more severe. The impacts of generic reactor problems and the need for corrective action might be hampered if the station staffs are relatively new and inexperienced, as discussed above. This might delay completion of the required modifications and further loss of electricity generation.

Typical of common-mode failures are events such as loss of off-site power, restart problems with emergency diesel generators (EDG) of gas turbines providing station emergency power, loss of intake cooling water supply, or limitation of hot water discharges from the cooling systems into local water bodies due to a rise in average water temperature particularly in summer months. A good example is a loss of off-site electric power event.[50] Off-site electric power is usually required to operate station in-house electric power consumption for running pumps, compressors, air conditioners, computers, office equipment, etc. Usually plant generation is up-voltaged in the station's transformer yard and sent to the grid, while the grid through a separate line provides low voltage power for station internal consumption. If the line carrying grid power to the station is cut due to an accident or deliberate sabotage action, then the station has to rely on internal electric power supplies provided by batteries (short duration supply to essential operations such as the control room), EDGs, or gas turbines. Both EDGs and gas turbines which are normally idle might fail to start up when suddenly called upon to generate. Should the station staff fail to start the emergency power sources, then an accident chain might be initiated with potentially severe consequences. If we are dealing with multiple-unit stations, the loss of off-site power might impact all units on site thus making corrective action and recovery more difficult. Such difficulties might be compounded if the station staffs are relatively inexperienced and not well trained in handling emergency situations.

The potential effects of common-mode failures within a multiple-unit station on the national electricity transmission grid should also be considered. This is both a safety concern and a point of vulnerability to terrorist attacks as discussed later. A multiple-unit station with an installed capacity of about 2,000 MWe, e.g., a 4 x 600 MWe Qinshan Phase II reactor station, represents a significant generation node injecting electric power into the grid. Such a station would represent about 1-10th of the total installed capacity in Pakistan. Should such a station shut down due to a generic design flow, or due to a common-mode failure, then the entire transmission grid in the regional vicinity might become unbalanced in that the load exerts a pull on the grid while the grid suddenly cannot supply the existing demand. In such a situation, the grid operators will attempt to shed some load centers to restore balance, call on reserve plants to generate, and shift available extra power from more remote regions to support the local demands. Depending on the existing grid equipment and experience of grid operators, such remedial actions might stabilize the system, or in the worst case might lead to a regional or total grid shutdown as happened in the U.S. Pacific grid partial blackout event of 2001, the U.S. Northeast blackout of August 2003,[51] and similar blackouts during the 2003-04 period in Italy, France, and elsewhere. Thus installing large multiple-unit nuclear stations might carry the additional risk of grid instability, which could be protected against to some degree, by constant beefing up of grid equipment and installation of multiple transmission lines at great cost. However, even better protected grids such as in the United States and European Union (EU) countries were found to be prone to blackouts as recently discovered. We cannot assume that the Pakistani electric grid will be free of disturbances whose consequences could be more severe when large nuclear stations are built.

Impacts of Natural Disasters.

Finally, the impacts of natural disasters on multiunit nuclear stations, on the electric grid, and on the interactions between the grid and the stations could not be ignored. Due to its geographical location, Pakistan is prone to earthquakes as was unfortunately discovered during the large-scale earthquake that hit the Northwest Frontier Province and the Kashmir area in October 2005. Furthermore, Pakistan is also prone to Monsoon floods hitting closer to the coastal areas. Any such naturally occurring event might severely impact the operation of a multiunit nuclear station if it is located in an area relatively near to the disaster's epicenter, or if the electric grid has been disturbed near the disaster area and grid instability has percolated to the location of the nuclear station. In either case, the combination of the direct effects of the disaster, ensuing transmission grid instability, and the possible initiation of a nuclear accident chain such as loss of off-site power, coupled with loss of on-site emergency power supply, could lead to very difficult consequences involving a severe nuclear plant accident. Such events could be exacerbated if a multiunit nuclear station is located near the disaster-impacted area and if the station staffs are relatively inexperienced and insufficiently trained in emergency response procedures.

PROSPECTIVE NUCLEAR STATION SECURITY PROBLEMS

Introduction.

In this section interactions and cross-impacts between Pakistani security issues and the proposed expansion of the Pakistani nuclear power system including multiunit nuclear power stations are discussed. The rapid growth rate planned for Pakistani nuclear power and its safety implications were reviewed above. Here related security implications are analyzed. A short review of some of the national security and stability issues particularly affecting Pakistan and their impacts on multiunit nuclear stations are considered. It is possible that large multiunit stations that would be constructed if the nuclear expansion plan is implemented might constitute tempting targets for terrorist attacks or military takeover, given their large size, economic importance, and significance as national growth and development symbols. These issues are discussed below. It should be stated, for fairness sake, that no case of terrorist attack against a Pakistani nuclear power station site, or any other nuclear site, is known to have occurred so far. Yet the past may not be an indication as to the future.

Pakistan's National Security Issues Possibly Affecting Power System Infrastructure.

In this section, discussion is limited to those national security considerations which might directly impact the Pakistani electric and nuclear power infrastructure. Specifically, the existence of terrorist organization networks and subnational instabilities and sectarian violence are discussed, all of which could be considered as sub-sets of the more general problem of the lack of democracy and the rule of law.

The inception of the Islamic terrorist infrastructure in Pakistan is related to the evolution of the state itself. Pakistan was ruled by the military for all but 6 years of its history as an independent state. The community is divided among Sunni and Shia followers of Islam. The state is controlled mostly by Punjabi elites, leading to ethnic tension with the Sindhi and Baluchi regions, Afghan refugees, and groups of foreign terrorist elements (Chechens, Arabs, Uzbekistanis, etc). The military regimes have failed to produce results for the country in terms of political and economic development, competition with India, and Pakistan's regional position. Several wars have resulted in the loss of the majority of Kashmir to India, East Pakistan (now Bangladesh), loss of control of Afghanistan, and an almost nuclear war situation with India in 2000. There is a high degree of availability of weapons and of heroin, opium, and other drugs coming from the mountainous regions near the border with Afghanistan, as a result of 25 years of continued strife in that area. The period 1970-80 brought the unsuccessful war with India and dismemberment of East Pakistan, the emergence of the Khomeini Shia revolution in Iran, the Soviet Invasion of Afghanistan, and the introduction of Wahabi Sunni influences into Pakistan by Saudi Arabia as a counterweight. All these were serious shocks to the state, its political system, and its citizens, with one result of all of the above being the feeling that the state as a civil institution had failed its citizens and a possibly better answer could be found in Islam and in the establishment of a strictly Islamic regime. The penetration of Islamic influences into the affairs of the state and into the armed forces was accelerated towards the end of the Bhutto regime, and particularly during the military dictatorship of General Zia ul Haq. The international Moslem insurgency win in Afghanistan against the atheistic Soviet Union further strengthened the push towards Islamization of the state.

During the last 30 years or so, the armed forces began to encourage the emergence of Islamic terrorist organizations as once-removed instruments of state power to bring pressure on India to accede to Pakistani demands in Kashmir and in Afghanistan. Terror groups were used to defeat the Soviet Russian invaders of Afghanistan, and then the Taliban movement was brought into existence and encouraged to establish a pro-Pakistani regime that would enlarge Pakistan's hinterland and enhance its overall position vis-á-vis India. Additionally, various irredentist movements have developed their affiliated terrorist groups to help carry out their sectarian strife aims. Among these are the rising Baluchistan insurrection, the Taliban attacks on Afghanistan from the Quetta region in southwest Pakistan, ongoing Shia/Sunni attacks, Sikh terrorism, and various other attacks related to the Pakistani and Afghan drug trade. A general discussion of the development of the Pakistani state, the role of the army in society, and the government's indirect encouragement and control of the Islamic terrorist movement are provided by Haqqani,[52] Ahrari,[53] and Isaac Kfir.[54] The political and terrorist unrest in Baluchistan,[55] in the Jammu and Kashmir area,[56] and in the North West Frontier Province (NWFP)[57] is also discussed. A subset of the large body of literature related to terrorism and Pakistan can be found in the prolific writings of B. Raman of India, who attempts to link state supported Pakistani terrorist groups and the quest for nuclear weapons,[58] as well as in other sources.[59] Ramen has reported in some detail on a Baloch Liberation Army (BLA) terrorist mortar attack on the PAEC nuclear installation near Dera Ghazi Khan in Balochistan on May 15, 2006, which resulted in a large fire in the nearby area.[60]

A listing of terrorist and extremist groups operating in Pakistan is shown in Table 4.[61]

Terrorist Groups		Extremist Groups
Domestic organizations	Transnational organizations	
1. Lashkar-e-Omar (LeO) 2. *Sipah-e-Sahaba Pakistan (SSP) 3. Tehreek-e-Jaferia Pakistan (TJP) 4. Tehreek-e-Nafaz-e-Shariat-e-Mohammadi 5. *Lashkar-eJhangvi (LeJ) 6. Sipah-e-Muhammad Pakistan (SMP) 7. Muttahidda Quami Movement - Altaf Hussain (MQM) 8. Haqiqi Muhajir Quami Movement (MQM-H) 9. Baluch People's Libration Front (BPLF) 10. Baluch Students' Organistaion (BSO) 11. Jamaat-ul-Fuqra 12. Nadeem Commando 13. Popular Front for Armed Resistance 14. Muslim United Army 15. Harkat-ul-Mujahideen Al-alami 16. Baluch Students' Organistaion - Awami (BSO-A)	1. *Hizb-ul-Mujahideen (HM) 2. *Harkat-ul-Ansar (HuA, presently known as Harkat-ul Mujahideen) 3. *Lashkar-e-Toiba (LeT) 4. *Jaish-e-Mohammad Mujahideen E-Tanzeem (JeM) 5. *Harkat-ul Mujahideen (HuM, previously known as Harkat-ul-Ansar) 6. *Al Badr 7. *Jamait-ul-Mujahideen (JuM) 8. Lashkar-e-Jabbar (LeJ) 9. *Harkat-ul-Jehad-i-Islami 10. Muttahida Jehad Council (MJC) 11. Al Barq 12. Tehrik-ul-Mujahideen 13. Al Jehad 14. Jammu & Kashir National Liberation Army 15. People's League 16. Muslim Janbaz Force 17. Kashmir Jehad Force 18. Al Jehad Force (combines Muslim Janbaz Force and Kashmir Jehad Force) 19. Al Umar Mujahideen 20. Mahaz-e-Azadi 21. Islami Jamaat-e-Tulba 22. Jammu & Kashmir Students Liberation Front 23. Ikhwan-ul-Mujahideen 24. Islamic Students League 25. Tehrik-e-Hurriat-e-Kashmir	1. Al-Rashid Trust 2. Al-Akhtar Trust 3. Rabita Trust Ummah Tamir-e-Nau

*Also listed in the U.S. Department of State 2004 Terrorist Report.

Table 4. Terrorist and Extremist Groups of Pakistan.

Terrorist Groups whose name is preceded by an asterisk are also listed in the U.S. Department of State's Annual Terrorism Report of 2004,[62] and information related to their activities is reviewed in the Congressional Research Service (CRS) report on Terrorism in South Asia.[63] Inspection of Table 4 indicates that currently there are about 48 domestic and international terrorist groups operating in Pakistan. This number in itself represents a record of sorts. Assuming that not all groups are really active, we can estimate about 40 active terrorist groups. As discussed above, the installed nuclear capacity in Pakistan is now about 450 MWe (Gross) comprised of KANUPP—137 MWe, and CHASNUPP-1—325 MWe. This is the equivalent of 0.45 GWe of installed capacity. A notional ratio of the number of active terrorist organizations per GWe of installed capacity can now be defined, and that ratio is found to be about 90 Terrorist Groups/GWe. Note that this is only a notional number, not implying that there are about 90 terrorist groups in Pakistan or that there is a firm GWe of installed capacity. This number represents an artificial ratio computed to make a point. Once CHASNUPP-2, which is now under construction, is completed, the installed nuclear capacity in Pakistan will increase to 775 MWe or 0.775 GWe. The ratio of terrorist organizations per GWe of installed capacity will then decline to about 52 Terrorist Groups/GWe. In the future, it can be assumed that with the general stabilization of South Asia and of Pakistan particularly, the number of active terrorist organizations in Pakistan might halve to about 20 organizations by 2030. At that point, the installed nuclear capacity is projected by the Pakistani Government to reach about 8,800 MWe or 8.8 GWe, and the notional ratio will decline to about 2.3 Terrorist Groups/GWe of installed nuclear capacity, still probably a world record. It should be considerd, however, that most terrorist organizations active in Pakistan will not have the capabilities or motivations for attacking nuclear power plants. Only a small number of the organizations listed in Table 4 present a possible danger to future nuclear power stations. All Pakistani nuclear installations are guarded by the army, and no attacks against nuclear power stations by such groups or others have occurred thus far. Yet the fact that *some* terrorist organizations are still capable or motivated enough to launch such a hypothetical attack, should give us pause.

Superimposed on the ratios developed above is the data shown in Figure 2,[64] depicting the number of sectarian violent incidents that have occurred in Pakistan till 2003. The data shown in Figure 2 indicate a positive long-term trend of a decline in sectarian violence. This decline is, however, punctuated by periodic episodes of large-scale eruptions of violence occurring about once every 4 years, and indicating an element of short-term instability in intersectarian relations that could manifest itself in future similarly violent episodes. The short-term instability feature indicated in Figure 2 could be detrimental to the evolution of nuclear power infrastructure, which requires a long-term stability trend. This is so due to the long lead-times for the development of nuclear power and fuel cycle facilities and due to the long-term need to acquire operators experience and good plant operating practices.

In summary, Pakistan is unique in having encouraged the development of a large terrorist infrastructure resulting in a significant number of terrorist organizations that are allowed to operate within the country. That terror system is also internally used in various episodes of sectarian violence that encom-

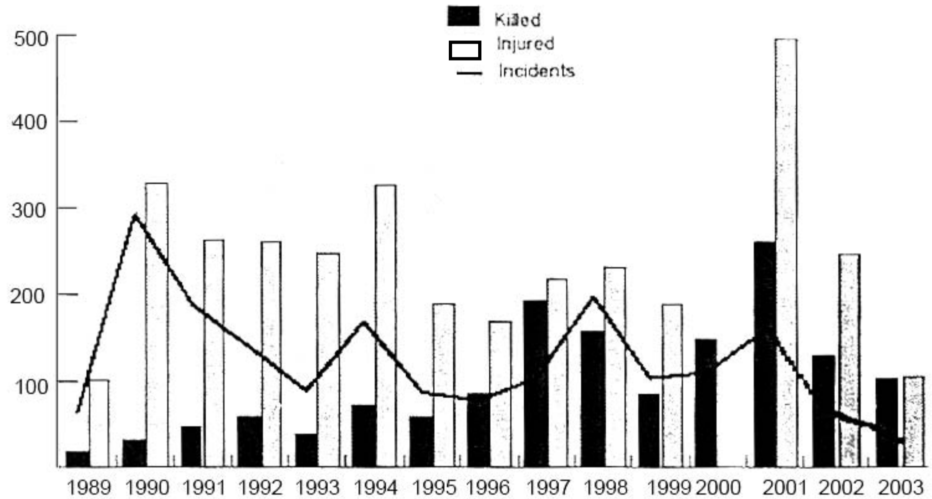

Figure 2. Sectarian Violence in Pakistan (1989-2003).

pass various minority groups within the diverse Pakistani society. There exists an ambiguity as to the relations of the regime to the terrorist organizations, some of which might have been utilized by the Government, one step removed, to accomplish irredentist goals in Indian Kashmir and in Afghanistan. Some elements of the terrorist infrastructure resident in Pakistan represent foreign terrorist groups (al-Qaeda Arabs, Chechens, Uzbekistanis) which were left stranded in Pakistan following the various Afghan wars which are only notionally controlled by the regime, and are allowed to pursue their specific grievances regardless of the interests of Pakistan itself. Sectarian violence is concentrated mostly in the large population centers such as Karachi and has not spilled far into the countryside where nuclear stations are (to be) located. However, it is questionable whether this climate is the most propitious for a significant nuclear power expansion plan, and some of the potential security risks involved are discussed next.

Missile Material Diversion from Nuclear Power Stations.

As mentioned above, a large amount of spent fuel will be discharged annually from the operating reactors in multiunit stations such as those planned for Pakistan, and will accumulate in the spent fuel storage pools. A 4 x 600 MWe reactor station will discharge on an equilibrium cycle about 100 MTHM/year from all four reactors, and that spent fuel will reside in the four pools located next to the reactor buildings on-site. As estimated elsewhere, the discharged first core is only partially "burned," does contain higher grade plutonium, and will lose its shielding protection earlier than equilibrium burnup spent fuel.[65] We have estimated that at least three new large stations will have to be constructed to meet the stated capacity expansion plans of PAEC. Each station will also store on an annual basis an equal amount of fresh fuel waiting to be loaded into the reactors during their annual refueling outages. Usually each reactor will have its outage at a different time to prevent significant contiguous loss of generation for the grid. This implies that fresh fuel supplies will reside for a significant amount of time in each multiunit station. Additionally, a large nuclear power station contains other radioactive sources such as cobalt irradiation sources, neutron sources, etc. that could be utilized by experienced saboteurs with technical education for the production of radioactive dispersion devices (RDDs). Within such a large station, there will likely be found some large lead shielded containers which might provide (nearly) adequate protection for the transport of radioactive sources or possibly long cooled spent fuel assemblies. In short, such large multiunit stations operated by PAEC might offer tempting targets—might in fact act as magnets—for future terrorist groups determined to obtain WMD capabilities.

As further indicated above, the large staffs required to operate such stations—within the range of 1,200 to 2,400 persons or even more—offer the opportunity for a terrorist group to recruit a staff member as insider support or coerce one, under various threats, to provide data and cooperation. Even within such a populous country as Pakistan, one can assume that the leadership of some terrorist group and nuclear station operators may well have roots in the same social group, which might ease prospective recruitment. It may be possible to assume that terrorist organizations might cooperate, with one group having developed an insider support providing control over that staff person to a different terror group interested in breaking into the station and diverting radioactive material. Furthermore, Pakistani intelligence, which might control components of the guard force in these power stations, or rogue elements within the intelligence apparatus, might provide a terrorist organization they cooperate with, with inside person(s) contacts. In this way, the putative attackers might gain information on site characteristics, location of sources, and means of transport; or even get active support in disarming various alarms and detection devices.

In summary, the future emergence of large nuclear power stations containing radioactive material, the existence of a large number of well-armed and well-trained terrorist organizations, some of which might be interested in acquiring WMD/RDD components and possess technical training, the potential for developing insider support to facilitate such attacks, and the fact that station staffs at some point might be relatively new and inexperienced and thus unable to protect their stations from outside attack, all point to the possibility that future nuclear material diversion attempts might prove successful. To be fair, we must point out that Pakistan has operated a nuclear reprocessing plant in Chasma, a uranium enrichment plant in Kahuta, and several other weapons facilities for almost 20 years, and no diversion attempts from these facilities are known to have occurred. Likewise, the IAEA has not recorded any diversion of nuclear material from facilities under safeguards in Pakistan thus far. It is possible that this is so, since these facilities were guarded by the military as parts of its nuclear weapons complex and thus were well-protected. It is not clear if future nuclear power stations operated by the civilian PAEC will be subjected to as thorough a protection by the military as the military weapons facilities, thus making prospective diversion from the power stations more feasible.

Terrorist Attack, Seizure or Takeover of a Nuclear Power Station.

Terrorist attacks on nuclear power stations in a complex society such as Pakistan, might be launched for other purposes than radioactive material diversion. A nuclear station might be attacked to create radioactivity release and dispersion, thus creating a major national and possibly international crisis and punishing the central government, or neighboring countries' governments, for having committed some sins (from the perspective of the terrorists). A terrorist attack on a nuclear power station─a government prestige project─might be launched to extract specific concessions from the government─release of captives, guaranteed amnesty, a change in specific government polices whether domestic or foreign—or to publicize some terrorist political demands against the government or against foreign governments. Finally, an attack against a nuclear power station might be launched during a period of regime change, political instability or regional sectarian strife when the terrorists might view the control of the station as a bargaining chip to extract from the incoming regime specific concessions for their organization or for a sectarian group they might claim to represent.

The considerations discussed above apply here: i.e., the desirability of attacking a nuclear power station as a government status symbol; the station might contain significant amounts of radioactive material the dispersion to the atmosphere of which might create havoc in nearby and possibly far off communities; terrorist organizations in Pakistan might be well-equipped, trained, and motivated—more so than some nuclear station staffs; the relative ease of securing or coercing insider support for an attack plan; and the possibility that a new nuclear station staff might not yet be well-trained and versed in security procedures, thus increasing the likelihood that a terrorist attack might succeed and that some elements in the government intelligence agencies might cooperate with the terrorists and support, if not encourage, their impending attack. The important point here is that a multiunit nuclear station will represent an attractive target for control by a terrorist organization. This is due to the immense publicity such attack might create which will provide free advertisement for the terrorist organization and its political demands. Due to the public fear created relative to the large accumulation of radioactive material on site, political pressure on the government to accede to the terrorist demands so as to prevent a nuclear catastrophe might be a result. The calculation of relative terrorist organization's attacking strengths (including possible insiders support and/or covert support by elements of the government intelligence agencies) vs. the weakness of the station security staff and military guards, might indicate that a prospective attack might well succeed.

These considerations indicate the unintended effect of constructing large multiunit nuclear power stations in a politically unstable country such as Pakistan, with its unique concentration of (partially government sanctioned) terrorist organizations. Under normal (politically stable) environment, constructing nuclear reactors within multiunit stations carries many advantages related to design standardization, on site replication, greater construction efficiency, and ultimately, improved operations efficiency. All these might result in significant cost savings over time. In Pakistan's unique situation, these advantages might be negated by the fact that such large national prestige projects could, perversely, become magnets for prospective terrorist attacks.

Airplane Attacks on Nuclear Power Stations.

A terrorist attack mode which has gained notoriety following the September 11, 2001 (9/11), attack on the World Trade Center in New York City and on the Pentagon in Washington, DC, is attack by airplanes on civilian targets, prospectively including commercial nuclear power stations. It has been revealed in the interrogation of captured al-Qaeda operatives since then that they contemplated, though never practically attempted to implement, coordinated aerial attacks on specific U.S. nuclear stations. It is also hypothetically possible that some rogue elements of the Pakistani Air

Force might attempt such attacks for purposes of their own. Airplane attacks could be mounted in two main ways:

1. kidnapping commercial passenger planes and flying them into the target, relying on the penetrating power of the airplane body and the engine turbine shafts to achieve containment structure penetration, and on the mass of jet fuel to catch fire and burn inside the breached containment; and,

2. smaller commercial aviation planes laden with explosives that rely on the explosive power of the total charge placed inside the planes to breach the containment structure.

To be fair, we should state that no airplane attack against a nuclear power station, let alone a multiunit station, has ever taken place, though again, this is no indication as to the future.

An airplane attack is different from the terrorist attacks discussed so far in that it is meant to breach at least one containment structure or spent fuel storage pool and cause a major radioactive release with all the attendant population exposure hazards along the radioactive plume's path. There is no mistaking the terrorist's intentions in mounting this sort of an attack, and all the ambiguities that might surround a terrorist action are swept away. The purpose here is clearly to punish the regime by hurting the civilian population so as to "pay" for having committed some sins against the terrorists or the people they might claim to represent.

If this is the terrorists' declared intention, then a multiunit nuclear station could be a useful target from their perspective. First, the symbolic nature of (even partially) destroying a prestige national project such as a large nuclear station cannot be understated. Second, if successful, such an attack might cause a significant radioactive release leading to casualties in the nearby and further away populations and potentially causing exposure in neighboring countries—India in Pakistan's case. Third, the economic damage to the station itself, to the regional and national electric grids, to the contaminated area due to loss of work and the expense of decontamination, and to the national economy due to loss of electricity supply and reduction in national productivity, could be substantial.

Furthermore a multiunit station is an attractive target since there is always the chance that if one reactor target is not hit, then another reactor or critical site facility might be hit. A reactor building is a relatively small target within all other structures to be found in a nuclear power station, including the turbine generator buildings, the cooling towers, the electrical buildings, and the transmission station. Near ground air turbulence might make it difficult to maintain aim and steadily point the airplane towards the reactor building. There exists, however, the possibility that in the last few seconds before the actual hit, even if the suicide pilot is deflected from hitting one reactor structure, he might still be able to point his plane and hit another reactor building. The chances of a successful hit on a multiunit station is then that much greater.

This is even more important if the terrorist pilot's intention is to hit the spent fuel storage pool and cause heating and meltdown of the stored fuel, with a release of the inventory of volatile fission products contained therein. The spent fuel pool is but a small appendage on top of the "wraparound" auxiliary building surrounding the reactor containment structure. It is difficult for the pilot diving on the power station and struggling to point his plane, to aim specifically at the spent fuel storage pool, if he can identify it at all. However, the pilot stands a greater chance of success on a multiunit station in that he might hit a different pool than the one he originally intended, since the choice of targets is multiple and more varied. In general, the more critical target structures are identified on-site, the greater the chance that at least one of them would actually be damaged, with all the attendant consequences. This is particularly true in a country such as Pakistan with a number of terrorist organizations, some of which might ultimately wish to hurt the central government in this way. PAEC's reasonable goal of multiple sitings of the nuclear units it plans to build might blow back on it by creating targets for high-consequences putative terrorist attacks.

Military Takeover of Nuclear Station Sites.

The discussion on possible military takeover of nuclear power stations follows the above discussion of potential terrorist attempts to occupy nuclear power sites. The major difference is that terrorist groups might intend to harm those facilities and cause radioactive leaks, whereas a military takeover of a nuclear facility might be more in the nature of acquiring political bargaining chips rather than harming the plants. We should recognize that all Pakistani nuclear installations, including power stations, are guarded by military units to start with. A takeover of the station implies local military control over the station disregarding central government orders. (The station's military guard force might belong to a different unit.) It may even suffice for the military just to hint that it might take full control over the nuclear power station to achieve its political aims, without even resorting to actual exercise of control.

Why would the military contemplate such a move? The reasons mostly involve a change of political regime in Pakistan where a regional corps commander might feel that his interests as a regional commander and as a representative of his region are not respected, or the commander might actually be threatened with dismissal by the new incoming regime. To maintain his position, privileges, and concessions to his region, the corps commander might notify the central government that unless his conditions are met, he might take control of the large nuclear power station located in his region from the special unit guard force. Alternatively, the corps commander might actually do so or just block lines of communications to the station. Under such threats or real action, the central government might accede to the regional commander's demands rather than face the possible consequences of his actions.

A large multiunit nuclear power station might be the logical target for such military/political maneuverings since it represents a national prestige project, of which the national government would be loath to lose control. The economic consequences for such loss of control and the political backlash might be worse, from the government's perspective, than the political fall-out from the fact that the government capitulated to the local corps commander and met his terms. Thus, taking over a nuclear station, or just threatening to do so, could produce benefits to regional military commanders viewing themselves under risk. This is another perverse result related to the fact that a large-scale nuclear stations construction program is planned for a country where the military presence and impacts on society are very pronounced. Pakistan has been referred to in the past as "A military with a country, rather than a country with a military."[66] In this climate where the military views the country as under its direct, or indirect, control, national prestige projects such as nuclear power stations could be used as hostages in political/military confrontations not of their own makings.

Foreign Military Attacks on Nuclear Power Stations Sites.

Future large nuclear sites in Pakistan such as multiunit nuclear power stations might prove tempting targets for foreign military attacks should Pakistan be embroiled in a war with any of its neighboring countries. Nuclear facilities have already been targeted in war situations, specific evidence being the Iranian aerial attacks on the Tuwaitha nuclear site in Iraq (home of the Osiraq reactor as well as other nuclear facilities), as well as the Iraqi air force attacks on the Bushehr nuclear power plant, then under construction in Iran. Both attacks occurred during the Iran-Iraq war of the 1980s.[67] The precedent of attacking nuclear power station sites has thus been established, though the Bushehr station was under construction and not yet operational, and did not contain nuclear fuel. The Tuwaitha site, on the other hand, contained radioactive material—the cores of the Osiraq and other research reactors on site, all under IAEA safeguards. This did not prevent another IAEA member country (Iran) from attacking the site. It should be noted that both Iran and Iraq were IAEA members, both signed the NPT, and both had safeguard agreements in force with the IAEA at the time of the Iran-Iraq war. Despite their treaty commitments, the Iraqis were developing nuclear weapons capabilities prior to the war, and the Iranians are most likely engaged in a similar program as a result of that war, this under the guise of developing a nuclear power program.

Prospective attacks on operating nuclear power stations could be considered under two scenarios. First is the preemptive takeover of a nuclear site to prevent it from being captured by an internal Pakistani terrorist organization during the general turmoil that a war brings. The aim here is protective—preventing potential destruction of the power station and possible radioactive release due to capture and damage by a nihilistic terrorist organization. Second is capture of a large operating nuclear station by an enemy country—India for instance—to deny electricity to the Pakistani government and disrupt the electric power grid remaining under Pakistani control. This would be a form of a sophisticated economic warfare in which the capture and denial-of-use of large infrastructure projects such as dams, refineries, or nuclear power stations might bring about the collapse of the enemy government regardless of other military offensives. In either case the actual destruction of, or significant damage to, the nuclear power station would not be contemplated as the attacking military might be aware of the potential consequences of a damaged nuclear plant, and would not want a nuclear debris plume to spread over its own country.

Under the scenarios listed here, multiunit nuclear power stations as well as military nuclear sites could be attractive targets for capture by an attacking foreign army. In order to assure the undamaged capture of such high value targets in the early stages of the war so as to prevent damage to the facilities that could be inflicted by either side through the "fog of war" situation, it is likely that a commando type operation would be planned and carried out by highly trained and disciplined military units. Such attacks might succeed without causing significant damage to the reactors, though the risks are great. Placing a relatively small one-unit nuclear power station in the path of an invading army is one matter. Constructing a multiunit nuclear power station in regions susceptible to war between neighboring countries (contemplated as recently as 5 years ago) raises the risks and consequence scales considerably.

CONCLUSIONS

In this chapter we have reviewed the current nuclear power situation in Pakistan and the plans and prospects for its significant expansion. We have then reviewed the safety and security of the prospective large multiunit nuclear power stations that will have to be constructed in Pakistan under its ambitious capacity expansion plan.

Our conclusions regarding the nuclear power growth prospects in Pakistan are ambivalent. Under the current rules of nuclear trade, it will be difficult to construct any large sized nuclear power reactors in Pakistan not yet committed. The U.S.-India nuclear power deal, if approved by the U.S. Senate and by the Nuclear Suppliers Group (NSG), could open the door to a similar deal with Pakistan to be possibly sponsored by China and supported by other nuclear suppliers such as Canada and potentially France or Russia. If such a deal is initiated, there is little doubt that Pakistan could effectively participate in the construction of future nuclear stations and be able to operate them. Successful world class operation of future Pakistani nuclear power plants depends to a large extent on improved communication and flow of technical support and training between the global nuclear power industry encompassing its various institutions, both private and public, and PNRA, PAEC, and Pakistani industry. Additionally, extensive training and retraining programs for all nuclear personnel will have to be instituted by Pakistani educational organizations supported by foreign technical experts. For that to happen, Pakistan's position within the NPT world community and the NSG would have to be regularized, possibly building on a modified (more stringent) version of the U.S.-India deal. Furthermore, the security situation in Pakistan will have to improve so that foreign experts could be assigned to work with, provide technical assistance to, and train their Pakistani counterparts without concerns for their personal safety and security.

The record indicates that even with limited technical contacts with the global nuclear power industry, Pakistan did well in preserving the safety of its operating plants and managed to maintain them in operation, though at lower capacity factors than achieved by other Asian countries better integrated into the global nuclear community. The raw potential for operational excellence is there, and it requires additional refinements to break through and shine.

The two limiting factors on the expected fast growth of the Pakistani nuclear industry are (1) the ability of the regulatory agency PNRA to license new sites and new power stations fast enough to meet the target expansion schedule and to properly supervise the safe operation of the constructed nuclear power stations, and (2) the ability of PAEC to train new plant operators and stations' O&M staff members to meet the staffing requirements of the newly established stations. It is yet to be determined whether the Pakistani technical institutes could train adequate numbers of new personnel fast enough to meet the expected demand. Lack of trained personnel could hamper the safe operation of future nuclear power stations and contribute to nuclear accident initiation.

Based on current information, Pakistan will most likely expand its nuclear capacity, if possible, relying on the Chinese reactor designs of Qinshan Phase I—a 300 MWe reactor and Qinshan Phase II—a newer 600 MWe unit. Pakistan will attempt to standardize its growing nuclear capacity by relying on a few standard designs with reference plants in operation. We estimate that to expand to the full extent of its plan—8,800 MWe of new installed capacity by 2030—Pakistan will have to license and open at a minimum three new nuclear sites, each site containing a 4 x 600 MWe station. In this way, Pakistan might enjoy the economic benefits of both plant standardization and on-site replication of identical units.

All plant standardization and replication programs do, however, carry inherent risks. If the reference design chosen happens to have unexpected technical problems that crop up only after years of operation, then all reactors built to that point will suffer from the same generic problem, and technical fixes will have to be retrofitted later into the operating reactors. Both Chinese designs contemplated by Pakistan are relatively new (particularly the 600 MWe units) with a limited operational track record and thus present risks that future problems might emerge. Should repairs and retrofits be required, these will result in economic penalties both due to the direct cost and due to lost generation from the repaired reactors while undergoing modifications.

The more serious consequence of a generic reactor problem is that it might lead to the initiation of an accident chain which could evolve into a full blown nuclear accident if the station's staff was still inexperienced and not very familiar with emergency procedures. Multiunit stations could further suffer from common-mode reactor failures caused by operational error within the station or within the electric grid—the loss of off-site power—or caused by natural disasters such as earthquakes or floods. All such events would further be exacerbated by new and inexperienced station staffs. We should realize that station operation and electric grid operation are interrelated. Common-mode reactor problems, which might shut down a nuclear station, might also cause cascading plant shutdown throughout the electric grid, which could eventually (under the worst case) lead to a grid collapse and electricity blackout with severe social and economic consequences.

Due to its unique characteristics, history, and the nature of its internal as well as external politics, Pakistan has allowed the emergence of an entire infrastructure of terrorist organizations within its borders. Up to 50 to 60 active or partially active terrorist groups are estimated to operate in the country in pursuit of their own nihilistic, sectarian, or pan-Islamic goals. It is further suspected that some of these groups receive direct or indirect aid from Pakistani intelligence or some rogue elements within the Pakistani intelligence community, which use terror tactics to promote Pakistan's interests in its conflict with India over Kashmir and its attempts to control the Afghanistani regime. Only a limited number of these organizations have got the requisite capabilities and the motivation to attack a nuclear power station, though such attacks have not yet materialized. In addition to this terror infrastructure, one should consider simmering regional and sectarian strife between the Punjabi and the Sindhis, the Punjabis and the Baluchis, and between the majority Sunni and minority Shia communities. On top of all these, we should consider the existence of large-scale foreign terrorist base areas within Pakistan, only partially controlled by the government, if at all. In this category, we include the Taliban and the International Islamic Group (al-Qaeda and their associate Chechen, Uzbekistani, Arab, and other groups). All these concentrate along the border areas between Pakistan and Afghanistan; however, they maintain active terrorist cells within the main Pakistani population centers.

The overall conclusion from this enumeration of the unstable environment within Pakistan is that the country may not present the most secure environment in which to construct a large system of nuclear power plants and their supporting infrastructure. Due to their long lead-times, all nuclear projects require long stable periods to allow licensing, construction, and successful operation. Thus a long-term stable security environment would be conducive to the development of a large nuclear power program within any country, and the converse is also true. Unfortunately, as discussed above, Pakistan is not a model of a stable country, and developing a large nuclear power program under these conditions might present considerable risks.

The risks that the terror infrastructure and unstable national security environment present to operating multiunit nuclear stations are diverse. Terrorist groups might initiate a diversion campaign or a direct attack against a multiunit nuclear station, relying in part on an insider's help, which they might recruit. Given the large number of terrorist groups existing, it is possible that some group might identify a sympathetic insider or coerce one into cooperation and pass him along to the group initiating the fissile material diversion operation. Terrorist groups might try to capture intact a nuclear station and use it as a bargaining chip in their negotiations with the central government regarding their own, or general political demands. Terrorist groups might, under some grievous conditions, attempt to destroy a nuclear station, creating large radioactive dispersion within Pakistan which could spread to neighboring countries. To achieve such a goal, the group might mount an aerial attack or use an explosive laden truck convoy to attack the station. Airplane attacks could come in two variants: (1) kidnapping and piloting a large passenger jet into a containment building or into the spent fuel storage structure on top of the auxiliary building next to the reactor, or (2) piloting several smaller commercial aviation planes laden with explosives placed there by the terrorists into the reactor buildings. In all cases, multiunit nuclear stations would be tempting targets for such kinds of attacks due to the multiplicity of high value targets. The prospective success of such attacks would be enhanced with insiders' support and assuming that the station staffs are yet new and not well-versed in emergency procedures.

Finally, the general political instability in Pakistan could lead to attempted takeover of nuclear power stations by regional military commanders during times of political turmoil, either to protect the stations, which are prestige national projects, or to use them as bargaining chips to secure conditions desirable to the commander, his command, or the sect he represents. Even the threat of a takeover might suffice rather than actual occupation. Such preemptive protective takeover of a nuclear station might be carried out by an invading army in case of a war between Pakistan and one of its neighboring enemy countries (e.g., India). This takeover would likely be carried out by commando-style attacks so as to prevent attempted terrorist attacks in times of general instability such as a war, or as a way to deny Pakistan the electricity the station generates until hostilities cease.

In general, the more attack scenarios against multiunit nuclear power stations that one can identify, the greater the indication that these type stations may not be the most desirable means of generating electricity in an unstable environment such as exists in Pakistan. This may happen despite the economic benefits that a well-managed and executed nuclear power program could bring, and despite the external assistance the Pakistanis might garner in implementing the program.

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