INDIAN MILITARY NUCLEAR PROGRAMME: TRAJECTORY AND FUTURE COURSE

ARJUN SUBRAMANIAN P

India started off with a peaceful nuclear programme. However, geo-political compulsions and the reality of international politics forced it to acquire nuclear weapons capability. India suffered a military defeat in a war forced upon it by China by illegally occupying a chunk of territory in Jammu and Kashmir (J&K). Less than two years later, China conducted its first nuclear test and was actively pursuing ballistic missile development programme. By 1966, China, for the first time, acquired a deliverable nuclear warhead that could be fitted on a ballistic missile. The Indian military nuclear programme was kick-started during this period. At present, India has advanced nuclear weapons capability that meets the requirements of the current threat scenario.

This article studies the Indian nuclear programme from the material perspective. India's route to nuclear weapons capability and the material factors that influenced it are discussed. Also, the external influencing factors – China and Pakistan and the recent attempt by Pakistan to lower the nuclear threshold to the tactical level—are looked at and its impact and efficiency are analysed. India's future nuclear weapons producing capacity to meet its future nuclear deterrence requirement is also analysed.

Mr. **Arjun Subramanian P** is an Associate Fellow at the Centre for Air Power Studies, New Delhi.

Research reactors like this, with very low burn up rate and which use (mostly) heavy water or graphite for moderation are the ideal type of reactors to produce weapon grade plutonium.

INDIAN NUCLEAR WEAPONS PROGRAMME

From the start, India's nuclear weapons programme has been based on plutonium (Pu) fuel. All the tests, including the 1974 Peaceful Nuclear Test (PNE), used Pu-239. A few factors may have contributed to the selection of plutonium over Highly Enriched Uranium (HEU). Firstly, India was operating a Canadian supplied heavy water moderated research reactor, which produces plutonium as a by-product. This plutonium can then be extracted and processed to obtain weapon grade plutonium. Secondly, plutonium has certain advantages over uranium like lower fuel requirement for a particular yield. Further, India probably started off with a peaceful nuclear programme, with the intention to just demonstrate its nuclear weapon capability. The device that was tested in 1974 was not of a weaponisable configuration.

PEACEFUL NUCLEAR EXPLOSION (PNE)

The Indian nuclear weapon programme sprang from its civilian nuclear programme. India developed what is called the CIRUS research reactor with Canadian assistance while the moderator (heavy water) was supplied by the United States.[1] It is a tank type reactor of 40 MW(t) capacity which uses natural uranium as fuel, heavy water as moderator, light water as coolant, B4C filled rods for control and has a neutron flux of 6.5x10^13 (n/cm^2/s).[2] Research reactors like this, with very low burn up rate and which use (mostly) heavy water or graphite for moderation are the ideal type of reactors to produce weapon grade plutonium. One other advantage is that such a reactor can be refuelled when it is online. Another option with this type of reactor is that target elements can be introduced while online

1. "Canadian-Indian Reactor, U.S", http://www.nti.org/facilities/832/, September 1, 2003.
2. D.K Shukla, "Safety Management and Effective Utilisation of Indian Research Reactors APSARA, CIRUS and DHRUVA", http://www-pub.iaea.org/mtcd/publications/pdf/p1360_icrr_2007_cd/papers/d.k.%20shukla.pdf , 2007.

where depleted or U-238 can be introduced for irradiation for a limited period which results in the production of fissile Pu-239. Probably, this was not done for India's PNE. The reactor is capable of producing 6.6 to 10.5 kg of plutonium a year at a capacity factor of 50 to 80 percent respectively.[3] However, the spent fuel from the reactor was reprocessed to obtain the fuel for the 1974 explosion.

India is not the only country to have conducted a PNE—the United States and Russia have conducted multiple PNE tests for various experimentations like civil engineering purposes, etc.

Work for the 1974 PNE actually began in 1964 when Prime Minister Lal Bahadur Shastri authorised the theoretical and technical ground work. Despite the prime minister being averse to weaponising India's nuclear capability, he had authorised the technical work to begin.[4] It is said that the Indian nuclear scientific community was desperate to demonstrate its capability, but the bigger push might have come from the first Chinese nuclear test a month earlier. Certainly, the Chinese test would have had a major influence on India's decision to go for nuclear testing as India had suffered its worst military defeat in the 1962 War which was a result of the illegal Chinese occupation of Indian territory. Some parliamentarians too were of the opinion that India should weaponise its nuclear capability as a deterrent to China.

India is not the only country to have conducted a PNE—the United States and Russia have conducted multiple PNE tests for various experimentations like civil engineering purposes, etc. The USA had conducted around 150 PNEs from 1957-75.[5] Hence, India was justified in conducting its own peaceful nuclear explosion. Further, the agreement with the USA and Canada stipulated that the fuel from the reactor be used only for peaceful purposes. India did conform to the agreement

3. "India's Nuclear Weapons Program: Present Capabilities". ",http://nuclearweaponarchive.org/India/IndiaArsenal.html, April 5, 2001.
4. "Nuclear", http://www.nti.org/country-profiles/india/nuclear/, August 2015.
5. "Peaceful Nuclear Explosions", http://www.world-nuclear.org/info/Non-Power-Nuclear-Applications/Industry/Peaceful-Nuclear-Explosions/ , July 2010.

as it was a peaceful explosion, as declared, and was not optimised for weaponising.

The PNE is claimed to have a yield of around 12 to 15 kilotonnes (kt), which is roughly the yield of the bomb dropped on Hiroshima, the only difference being that the design was not a weaponisable configuration, possibly being a less sophisticated assembly of fuel material, with a little excess of plutonium for the desired yield, less amount of high explosive, and less efficient tampering. In fact, the weapon was less sophisticated, considering the possible amount of fuel used and other devices like High Explosive (HE) lenses as the trigger. The bomb was of the implosion type, the kind that was dropped on Nagasaki, however, the yield of the Indian bomb (12-15kt) was lower than that of Fat Man (20-22kt). Fat Man used around 6.2 kg of plutonium to produce the given yield, while the Indian bomb could have used the same amount of plutonium or a little more (this is determined by the quality of the plutonium core and the efficiency of the bomb design, like tampering, etc.), given that it used just 12 fast-slow HE lenses, where each lens weighed 100 kg,[6] which amounts to a total lens mass of 1,200 kg. Whereas the Fat Man design (the Indian bomb appears to be more or less based on the Fat Man design, given that the fast and slow explosive material design as well as the type of HE material used in the device was similar[7] – the only exception was that the structure of the lenses was different) and used a 32 lens soccer ball structure where each weighed 63 kg (hexagonal) and 43 kg (pentagonal) with a total lens weight of 1,836 kg.[8] This is one reason why Fat Man had a higher yield compared to the Indian device. Further, the detonators are claimed to be lead azide spark gap detonators which are less sophisticated than the Exploding Bridge Wire (EBW) design.[9]

Despite all the preparations for the test going on for years, it caught the world by surprise, including the United States. Only the US State

6. "India's Nuclear Weapons Program: Smiling Buddha: 1974", http://nuclearweaponarchive.org/India/IndiaSmiling.html, November 8, 2001.
7. Ibid.
8. "The First Nuclear Weapons", http://nuclearweaponarchive.org/Nwfaq/Nfaq8.html, July 3, 2007.
9. n.6 .

Department's Bureau of Intelligence and Research (INR) raised any suspicion about India testing a nuclear device. However, the probability of the Indian political establishment authorising such a test was believed to be low at the time.[10] This was known from the later declassified US Embassy-India cables.[11]One other geo-political factor that may have been an immediate trigger for the authorisation of the test was the Nixon Administration's opening up of friendly relations with China, with President Nixon's visit to China in early 1972. With the warming of ties between the US and China, any hope of US assistance to India in case of aggression by China would have faded.[12] In addition to this, the *Enterprise* incident during the 1971 War clearly pointed to the hostile nature of US policies against India. This clearly put India in an unfavourable situation as far as China was concerned. These scenarios may have pushed India to build nuclear capability for self-defence. Hence, all the factors, including the effects of the non-alignment policy and the geo-political scenario of the time played a role in making India demonstrate nuclear weapons capability to build deterrence capability against its northern neighbour.

ROLE OF THE PURNIMA-I REACTOR IN THE 1974 PNE

As fuel for the bomb was a problem then, some separated plutonium from the CIRUS reactor, about 18 kg, was used in the indigenously built research plutonium reactor for the Neutron Investigation in Multiplying Assemblies (PURNIMA)-I.[13] It was planned that the fuel for the bomb would come from the PHOENIX plutonium separation plant in Trombay. However, the plant suffered a leak and was shut down in 1970; the hopes of restarting the plant quickly faded by late 1972, and PURNIMA was using the separated plutonium from CIRUS. It was then that the decision was taken to shut down and dismantle PURNIMA-I to divert its fuel for bomb making. In early 1973,

10. "The Nixon Administration and the Indian Nuclear Program, 1972-1974", *National Security Archive Electronic Briefing Book*, No. 367, December 5, 2011, Available at: http://nsarchive.gwu.edu/nukevault/ebb367/
11. Ibid.
12. Ibid.
13. Taraknath V.K Woodi, William S Charlton, Paul Nelson, *India's Nuclear Fuel Cycle: Unraveling the Impact of the U.S-India Nuclear Accord* (Morgan and Claypool Publishers), Ch. 2, p.9.

the reactor was shut down and the fuel was later utilised in the 1974 PNE.[14] Apart from this, PURNIMA-I helped Indian nuclear scientists to study and experiment with weapon fission characteristics. Indian scientists visiting the Soviet Union in the late 1960s were impressed with the plutonium fuelled, pulsed fast reactor which could be used for studying the fission bomb. This was the same type of reactor used during the Manhattan Project to perform the "tickling the dragon's tail" experiments. The Indian Atomic Energy Commission (AEC) approved the building of PURNIMA-1 in 1969 and the reactor attained criticality in May 1972. As a pulsed fast reactor, PURNIMA-I operated on much the same principles as a rudimentary fission bomb. This gave the Bhabha Atomic Research Centre (BARC) scientists benchmark calculations on the behaviour of a chain-reacting plutonium system and the kinetic behaviour of the system just above criticality. These calculations were used to determine the optimum explosive power and the neutron trigger of future bombs.[15] Apart from this reactor, by 1964, India had a large number of specialists working on plutonium metallurgy, who would have been immensely valuable in making the fuel core design for the bomb.[16] The plutonium core for the bomb was fabricated by a team led by PR Roy of BARC's radio-metallurgy department, who had also made the plutonium fuel rods for PURNIMA.[17]

THE 1998 UNDERGROUND TEST: WEAPONISATION

India finally went nuclear in 1998 when it tested five weaponisable nuclear devices in May that year. The tests were in the planning stage for several years which, however, got postponed due to some reasons each time. The last attempt before the May tests was during the 13 days when the Bharatiya Janata Party (BJP) was in power. It is said that the weapons were actually placed in the shafts, ready to be tested. However, the plan was aborted when it became clear that the government would not survive the vote of

14. n.6 .
15. "Purnima I-II-III", http://www.nti.org/facilities/861/, September 1, 2003.
16. George Percovich, *India's Nuclear Bomb: The Impact on Global Proliferation* (University of California Press, 2001), Ch. 2, p.71.
17. n.6 .

confidence which would prevent the administration from effectively dealing with the aftermath of the tests.[18] The 1998 tests involved five devices—one thermonuclear and the rest were fission devices. Among the fission devices, one was a 12-15 kt yield fission device and the rest were sub-kilotonne weapons. The tests were conducted in two phases: the first set was on May 11 when three devices were fired simultaneously with one being the 45 kt thermonuclear device, the second being the 12-15 kt fission bomb and the third, the sub-kilotonne device. The firing of the other two sub-kilotonne devices was done on May 13.

WHY SUB-KILOTONNE? A POINTER TO TACTICAL NUCLEAR WEAPON

The idea behind the sub-kilotonne weapons tests is not understood. Neither is it known if the design was weaponised. Going by the fuel, which was plutonium, the size of the core would have been comparatively small. Even the most conservative guess would make it a 2 or 3 kg one, which again depends on the design efficiency of the weapon. Details available on the public domain indicate that around 3 kg of plutonium might have been used. According to Chengappa, the plutonium for the devices weighed 3 to 8 kg.[19] If the design efficiency is high, the amount of fuel would be low, resulting in reduced size of the fuel core. Further reduction in the size of the weapon depends on the geometry of the high explosive lenses and the other triggering mechanisms. Now, the question arises, did the Indian government or at least did the scientific community involved in the test, have tactical nuclear weapons in mind? (Here, the term tactical is used in relation to the yield of the weapon.) Apart from the yield, the size and weight [which determine the carrier vehicle (for a tactical role)] of the nuclear weapon can also be questioned, given that the only missile delivery vehicle at that time was the Prithvi. If the lowest amount of plutonium used was indeed 3 kg in the 1998 test, then it is possible that the size and weight of the low yield design would have been heavier than a specifically built

18. "India's Nuclear Weapons Program: Operation Shakti: 1998", http://nuclearweaponarchive.org/India/IndiaShakti.html, March 30, 2001.
19. Ibid.

This idea of proportional retaliation emerged only after Pakistan tested its tactical nuclear delivery vehicle and lowered the nuclear threshold to the tactical level.

tactical nuclear device (considering the Cold War tactical nuclear weapon designs).

Certainly, there are some sections within the Indian strategic community who vouch for proportional retaliation if Pakistan were to ever use tactical nuclear against Indian forces, either in India or outside Indian soil, which is in contrast to the official nuclear doctrine that any use of nuclear weapons against India, irrespective of the yield will be considered as a first strike and will be responded with retaliation that will be massive and unacceptable. This idea of proportional retaliation emerged only after Pakistan tested its tactical nuclear delivery vehicle and lowered the nuclear threshold to the tactical level. However, till date, it is not known if Pakistan is building the tactical nuclear weapon that is compact enough to be delivered using the Nasr ballistic missile. The feasibility of Pakistan acquiring tactical nuclear weapon capability will be assessed later in this article.

SIZE OF INDIAN NUCLEAR ARSENAL

Estimates available in the public domain on the number of nuclear weapons in the Indian arsenal are of between 80 to 120 warheads. *The Bulletin of Atomic Scientists*, published in 2012, estimates that the Indian nuclear forces have approximately 520 kg of weapon grade plutonium, sufficient for around 100 to 130 weapons. The *Bulletin* also believes that India has not weaponised all of its plutonium stockpiles—just 80-100 weapons.[20] However, the yield distribution of the Indian arsenal is not known i.e India tested five devices of various yields in weaponisable configuration, but the deployment distribution of these designs is not known. The distribution and the actual number could throw light on India's nuclear threat perception and its minimum deterrence estimation. However, when it comes to the number of

20. Hans M. Kristensen, Robert Norris, "Indian Nuclear Arsenal 2012", *Indian Nuclear Forces 2012*, *Bulletin of the Atomic Scientists*, May 30, 2013.

nuclear weapons needed, it might not strictly be restricted to the threat perception, and there are other factors too that might play a role in the numbers game. For example, India has just begun to diversify its nuclear strike vectors (platforms) by establishing the third leg of deterrence. Assuming that India had already met its minimum deterrence requirement on land, the sea vector would lead to further build-up of weapons that have to be deployed in the SSBNs (Strategic Submarine Ballistic Nuclear).

Some shortcomings regarding operational constraints due to the design and range of the missiles might force India to opt for a better and bigger design, with a greater number of launch tubes and longer range missiles like the K-4, which is under development.

The present status of the Indian sea-based deterrent is the INS *Arihant* SSBN with the Sagarika (K-15 or B05) Submarine Launched Ballistic Missiles (SLBM). The *Arihant* design has four launch tubes which can carry three Sagarika missiles each. Some shortcomings regarding operational constraints due to the design and range of the missiles might force India to opt for a better and bigger design, with a greater number of launch tubes and longer range missiles like the K-4, which is under development. Further, India would increase the number of SSBNs it deploys at sea. This might push up the number of nuclear weapons required. It is to be noted that nuclear weapons deployed in an SSBN would be in a ready to fire state (yet with all the checks and safety measures in place), with the weapon mated to the missile.

THREAT PERCEPTION

Certainly, the improving Chinese nuclear strike capability which is already way ahead of India's does loom large in the Indian threat perception. China has an active ballistic missile development programme. While the Indian nuclear weapons' highest yield tested was 45 kt [Shakti-I (1998) thermo nuclear device], it was claimed by senior Indian nuclear scientists that the yield of the weapon could be raised to 200 kt, if required, without further testing. The others were all fission devices with just one with comparatively higher yield (13 to 15 kt), and the rest, sub-kilotonne yield. In comparison, China has a larger arsenal as well as weapons with far higher yield. The highest yield weapons with China are 3 and 4 megatonnes (Mt). Combined with highly accurate (some variants have terminal guidance) long range ballistic missiles, their nuclear strike and precise calculated damage causing capability is quite advanced. Since India had declared a unilateral moratorium on nuclear testing, it is not likely to develop high yield weapons of the order of megatonnes yield. Yet, logically speaking, India should opt for deploying a higher number of nuclear weapons to compensate for the reduced yield.

As far as Pakistan is concerned, India appears to have a comparative edge in nuclear weapons and delivery capability. The Pakistani nuclear weapons' yield is more or less equivalent to India's fission devices[21] except for the absence of thermonuclear weapons. However, Pakistan's weapons capability is primarily being used by it like a fence against an Indian punitive retaliatory conventional strike. With India believed to have come up with the new conventional battle doctrine to fight a limited but high intense short duration war to keep it under the nuclear threshold (as believed), which defeats Pakistan's idea, Pakistan has attempted to lower the nuclear threshold. Pakistan had tested what it calls the tactical nuclear delivery vehicle called the Nasr which has a range of 60 km.[22] The purpose of this ballistic missile nuclear weapons delivery vehicle would be to strike Indian conventional forces advancing into Pakistan's territory in times of war. India responded by stating again categorically that any nuclear strike (a generalised term which conveys that India does not differentiate between a tactical and a strategic nuclear strike) in its territory or its forces anywhere else would be considered as a first strike and would be met with a massive and unacceptable retaliatory nuclear strike.

However, there might be considerable worry as these tactical nuclear weapons, owing to the kind of command and control set-up they would necessitate and given the radicalism and terrorism in Pakistan, if actually

21. "Pakistan Nuclear Weapons", http://fas.org/nuke/guide/pakistan/nuke/
22. "Tactical Ballistic Missile", http://www.military-today.com/missiles/nasr.htm

used, which would result in a nuclear crisis of unimaginable magnitude. But before contemplating such a scenario, it needs to be looked at whether Pakistan will be able to design and develop a tactical nuclear weapon small enough to be fitted into the Nasr. Further, how effective such a tactical nuclear strike would be in stopping Indian conventional forces. The following paragraphs would briefly look at such factors.

LOWERING THE THRESHOLD: PAKISTAN'S TACTICAL NUCLEAR PROGRAMME

As far as the intentions are concerned, it appears Pakistan is serious about its tactical nuclear weapons capability. In the month of October 2015, Pakistani Foreign Secretary Aizaz Chaudhry stated that Pakistan has developed low yield nuclear weapons to deal with India's so-called Cold Start conventional military doctrine. This was the first time that a senior Pakistani official has given an explanation on the country's decision to build tactical nuclear weapons.[23] However, despite the statement, it is not clear if the tactical nuclear weapons he mentioned are new designs, using plutonium fuel, small enough to arm the Nasr ballistic missile. It is to be noted that Pakistan, in its nuclear tests in 1998, in response to the Indian tests the same year, had tested some uranium fuelled sub-kilotonne weapons too. It is possible that he was referring to those sub-kilotonne weapons which could be used tactically with Pakistan's existing Short Range Ballistic Missiles (SRBMs) or nuclear strike aircraft. Nevertheless, if indeed the foreign secretary was referring to a new tactical nuclear weapon, small enough to be delivered by the Nasr, then it is an indication that the weapon will be plutonium fuelled, obtained from Pakistani plutonium production facilities.

PAKISTAN'S WEAPON GRADE PLUTONIUM PRODUCTION CAPACITY

Pakistan's primary weapon-grade plutonium production facility is the Khushab nuclear complex in Punjab province. There are four nuclear reactors

23. "Pakistan Develops Nuclear Weapons to Combat Possible War with India", http://www.defencenews.in/defence-news-internal.aspx?id=L8A0E08WCf8= , October 20, 2015.

The Nuclear Threat Initiative (NTI) estimates that all the four reactors can together produce 24-48 kg of weapon grade plutonium. This would be sufficient to produce around 10 nuclear weapons. The Khushab facility has a heavy water production facility as well.

capable of producing plutonium which can be used to produce nuclear weapons after processing. These reactors use heavy water as moderator and natural uranium as fuel. Heavy water moderated reactors are suitable for producing plutonium which can be processed to extract weapons grade plutonium. The fourth reactor is believed to have been operationalised recently. The confirmation was based on satellite imagery.[24] The Institute for Science and International Security (ISIS) estimates the thermal capacity of the reactor to be 50 MW (t), while the capacity of the first three reactors, as estimated, is 40-50 MW(t).[25] The Nuclear Threat Initiative (NTI) estimates that all the four reactors can together produce 24-48 kg of weapon grade plutonium.[26] This would be sufficient to produce around 10 nuclear weapons. The Khushab facility has a heavy water production facility as well.

The other facility in Chashma is being built with Chinese assistance (the reactor is an indigenous Chinese Qinshan 1 reactor design). Two of the four reactors in this facility are still under construction at the time of writing this article. These reactors are not of much concern regarding weapon grade plutonium production as these are pressurised water reactors using light water as coolant and moderator. Hence, such reactors are not suitable for a weapons programme.

When it comes to designing a bomb with plutonium, it would not be a major hurdle for Pakistan as its HEU fuelled warhead is based on the implosion design.[27] Plutonium fuelled bombs would necessitate an implosion design. However, plutonium-based implosion devices are

24. "Pakistan's Fourth Nuclear Reactor at Khushab Now Appears Operational", http://timesofindia.indiatimes.com/world/pakistan/Pakistans-fourth-nuclear-reactor-at-Khushab-now-appears-operational/articleshow/45919653.cms, January 17, 2015.
25. "Khushab Complex", http://www.nti.org/facilities/940/ , December 13, 2013.
26. Ibid.
27. "Pakistan's Nuclear Weapons", http://fas.org/nuke/guide/pakistan/nuke/

complex compared to HEU fuelled weapons. Plutonium handling, temperature maintenance inside the warhead and taking care to prevent premature initiations from loose neutrons from the other plutonium isotope, are some of the complexities, but for a state like Pakistan these would be minor hurdles.

The question of miniaturisation of the bomb would be quite feasible and that is the exact reason why Pakistan has opted for producing weapons grade plutonium. The United States and the Soviet Union have tactical nuclear weapons. A Cold War news report—some believe it to be a rumour—claims that the Soviet KGB has suitcase nuclear bombs i.e. a nuclear bomb small enough to be fitted in a suitcase, which can carried around.[28] Further, the US had what is known as the Davy Crockett field level nuclear weapon that could be fired using a recoilless sort of weapon operated by a two-man crew. The weapon (W54) weighed just 76 pounds, and had a length of 79 cm and a diameter of 28 cm.[29] There are other tactical nuclear weapons with higher yields, in some cases around 10 kt, that could fit into the Nasr payload section.[30] Hence, miniaturisation, though complex by design, is quite possible to achieve by a state like Pakistan which can muster sufficient resources.

The question of miniaturisation of the bomb would be quite feasible and that is the exact reason why Pakistan has opted for producing weapons grade plutonium.

One important question is, how much damage can it bring to the Indian armoured formations that would be thrust into Pakistan? Will the tactical nuclear weapons be able to stop an Indian armoured advance? An armoured column is considered here because that would form the main strike element which will be combined with mechanised infantry. The Indian government

28. "Congressman Weldon Fears Soviets Hid A-Bombs Across US", http://www.nti.org/analysis/articles/congressman-weldon-fears-soviets-hid-bombs-across-us/, October 26, 1999.
29. Alan Bellows, "Davy Crockett: King of the Atomic Frontier", http://www.damninteresting.com/davy-crockett-king-of-the-atomic-frontier/ ,
30. National Institute of Advanced Studies, Bangalore, had done a detailed analysis on this subject including dimensions of the Nasr. Available here: http://isssp.in/wp-content/uploads/2013/07/R17-2013_NASR_Final.pdf

and the armed forces have denied the term 'Cold Start'. Comments have come up regarding a strategy called 'Proactive Strategy' which is basically an idea for faster mobilisation for bringing in the element of surprise on the enemy, and for quicker attainment of the objective, and to keep the conflict below the nuclear threshold. Such objectives would anyway require a motorised advance which would be the armoured columns, supported by motorised infantry.

Coming to the effects and the utility of such tactical nuclear weapons on advancing armoured columns, it is pertinent to look at the weapon effects. One variant of the W54 had a yield of 0.2 to 1 kt. Now, the yield of the Pakistani tactical nuclear weapons is not known. Aiziz Chaudhary had termed it as a low-yield nuclear weapon and not a sub-kilotonne nuclear weapon. However, a sub-kilotonne weapon would still fall under low yield. For Pakistan to have a miniaturised warhead with yield above 2 kt, the design efficiency would have to be very high, with highly effective tampering around the core, while still achieving a weight within the payload limit. In some cases, beryllium which is an efficient neutron reflector is used for the purpose of providing tampering. Even if the yield is more than 1 kt, it would not be sufficient (considering the blast effects alone) to stop an Indian advance. AH Nayyar and Zia Mian have done a detailed analysis on the subject in their paper "The Limited Military Utility of Pakistan's Battlefield use of Nuclear Weapons in Response to a Large-Scale Indian Conventional Attack".[31] The conclusion of their study states that the tactical nuclear weapons would not be effective in stopping an Indian armoured advance. Even if they are designed for enhanced radiation effects, like the US' Davis Crockett, they would not be sufficient to stop an Indian advance. However, they might slow it down as some of the infantry would be affected by the high radiation dose. But this slowdown might not be significant enough to have any major impact on the operations.

31. AH Nayyar and Zia Mian, *The Limited Military Utility of Pakistan's Battlefield use of Nuclear Weapons in Response to Large Scale Indian Conventional Attack* (Pakistan Security Research Unit, University of Bradford , November 11, 2010).

The Indian nuclear doctrine, as explained above, does not differentiate between a tactical and a strategic nuclear strike, be it within Indian territory or on Indian personnel outside its borders. India would go for massive and unacceptable nuclear retaliation if ever attacked with nuclear weapons. In this scenario, wherein Pakistan's tactical nuclear force would not serve its intended purpose and would meet with massive Indian retaliation, it would make no sense for Pakistan to deploy these so-called tactical nuclear weapons.

INDIAN NUCLEAR TRAJECTORY

Given the threat scenario, India has a reasonably good arsenal to deter any nuclear eventuality with Pakistan. Pakistan's tactical nuclear weapons production would not affect the Indian nuclear deterrence capability much. However, India could improve the accuracy of its missile delivery systems for better targeting efficiency. With respect to China, India may have to increase the number of delivery vehicles capable of reaching the eastern sea board of the People's Republic of China (PRC) which comprises most of its economic hub. Further, India having declared a unilateral moratorium on nuclear testing, might have to increase its nuclear weapons arsenal, not to match China's but to affect better deterrence with it, given the bigger size of China's vital cities and the number of such potential targets in its eastern and southeastern parts.

INDIAN WEAPON GRADE PLUTONIUM PRODUCTION CAPABILITY AND EXISTING STOCKPILE

Some estimates put India's total weapon grade plutonium inventory between 445 to 530 kg, as of 2004. David Albright, in his paper titled "India's Military Plutonium Inventory, End 2004" had considered various factors such as the number and type of plutonium producing research reactors in India, their operating capacities (thermal) at various times, the amount of plutonium produced, and the possible amount of fuel consumed in the 1998 nuclear testing. He puts the number as of 2004, at between 445 and 530 kg. With this number, considering 4 to 7 kg of fuel per bomb, the total

Apart from the CIRUS, BARC operates other research reactors that could produce plutonium both as a by-product and via irradiation. The biggest source of reactor grade plutonium in India is from the line of indigenous Pressurised Heavy Water Reactors (PHWRs).

inventory would come to around to 100 weapons.[32] Since then, India would have produced more Weapon Grade Plutonium (WGP). In 2010, as part of the Indo-US nuclear deal, the CIRUS reactor was shut down and a year later its nuclear fuel was transferred to Trombay for reprocessing.[33] Apart from the CIRUS, BARC operates other research reactors that could produce plutonium both as a by-product and via irradiation. The biggest source of reactor grade plutonium in India is from the line of indigenous Pressurised Heavy Water Reactors (PHWRs). It is estimated that, as of 2006, India had accumulated about 11.5 tonnes of reactor grade plutonium from its PHWRs and it is also speculated that a major fraction of the plutonium would have been separated.[34] Another source for plutonium would be the India fast breeder programme. All the plutonium production reactors operational now would remain out of international safeguards.

The Prototype Fast Breeder Reactor (PFBR) has a thermal capacity of 1,250 MW and uses mixed-oxide fuel in the core and depleted UO2 in the radial and axial blanket regions.[35] A study on Weapon Grade Plutonium (WGP) production capacity by the PFBR was undertaken by Alexander Glaser and MV Ramanna. As per their study, the PFBR would be able to produce 144 kg of WGP annually (if separate processing of the radial and axial blanket is undertaken). The reactor could also be operated in the military mode, but if more than 35 percent of the plutonium is diverted (including the processing loss), the reactor will not be self-sufficient. However, to make it

32. David Albright, "India's Military Plutonium Inventory, End 2004", ISIS, May 7, 2005.
33. "Research Nuclear Reactor CIRUS to Shutdown Permanently on December 31", http://www.dnaindia.com/mumbai/report-research-n-reactor-cirus-to-shutdown-permanently-on-december-31-1482987, December 18, 2010.
34. Alexander Glaser and MV Ramana,"Weapon Grade Plutonium Production Potential in the Indian Prototype Fast Breeder Reactor", *Science and Global Security, 2007*, p.97.
35. Ibid.

sustainable, India could use the reactor grade plutonium from the PHWR to compensate for the diversion of fuel for the weapons programme.[36] The study also finds that if India were to successfully implement its plan to build and operate a total of five fast breeder reactors by 2020, WGP production could reach 700 kg per year. India could sustain this level of production for several decades without building additional heavy water reactors.[37]

The PFBR would be able to produce 144 kg of WGP annually (if separate processing of the radial and axial blanket is undertaken). The reactor could also be operated in the military mode, but if more than 35 percent of the plutonium is diverted (including the processing loss), the reactor will not be self-sufficient.

CONCLUSION

At this rate of plutonium production, India could not only sustain its three-stage civilian nuclear programme, but also cater for any future demand in increasing its nuclear stockpile. In the coming decades, the sea leg of India's deterrence could demand production of more nuclear warheads to be deployed in the SSBNs. Moreover, the targeting requirements for China might require further increase in the credible minimum requirement mark. Another compelling factor for India in the future might be the possibility of Pakistan switching over to producing plutonium fuelled weapons from the current HEU-based weapon. One advantage of this would be that plutonium fuel would be less attractive for non-state actors to build a nuclear weapon since it is design-wise more complex and also it is quite tricky to handle plutonium fuel, as an isotope releases stray neutrons that my set-off a chain reaction prematurely. Otherwise, the coming decades could see several factors primarily emanating from Pakistan and China that might influence the Indian nuclear deterrence calculus for the future.

36. Ibid., p.100.
37. Ibid., p.100.