The Challenge of Nuclear Modernization

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India's adoption of nuclear deterrence as a foundation of its defence strategy in 1998 marked a historic break from a half-century of incremental and reluctant nuclearization.[1]Since then, the Indian nuclear arsenal has undergone a steady modernization process that has brought considerable expansion of its capabilities.This paper briefly reviews the changes that have taken place over the past two and a half decades and highlights its key anomalies as well as gains.Given India's emergence as a potential great power in world politics, it is unsurprising that its capabilities as a nuclear-armed statehave exhibited a concomitantly rising profile. Below, I take stock of the pros and cons relating to the modernization process.

Some critical questions need to be considered. How does its espousal of a minimalist nuclear doctrine square with India'sgrowing nuclear capability? And to what extent are its doctrine and posture in accord with the technological developments that affect nuclear weapons today?In my view,there are significantdiscrepancies in India's nuclear strategy in two respects. First, Indian nuclear strategy has broken away from its minimalist moorings and is being pulled in different directions, with one trend retaining its original prudence and the other moving steadily toward unbridled expansion. Second, the strategy has not come to grips with the nuclear-conventionallinkage both in terms of the wider ramifications of older technologies and in the context of new developments in dual-use technology such as cyber technology and artificial intelligence (AI).

Thus far, the contradictions are not serious, but they are inadequately understood in the first place and have the potential to generate costly results. On the other hand, there are indubitably important strategic gains that critics tend to overlook.In a fundamental sense, notwithstanding the carping of some critics, India has gained a sense of security from major attacks by inimical neighbours. The technological changes that have affected nuclear weapons also contribute a set of security gains relating to national security. In addition, nuclear weapons have bolstered India's image and therefore influence as a major power in global politics.

The next section is a brief survey of the historical backgroundto India's adoption of nuclear weapons and outlines the broad process of India's nuclear modernization. The section that follows brings out the costs and risks attached to the possession of nuclear weapons and their modernization. Thereafter, I examine the gains that have accrued from nuclear possession and modernization. The conclusion highlights the conundrum faced by policymakers faced with the simultaneous operation of the tensions produced by these contradictory realities and suggests an optimal approach to try and resolveit.

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[1]Happymon Jacob, "The Concept of Nuclear Learning: A Study of the Indian Experience," in Feroz Hassan Khan, Ryan Jacobs and Emily Burke, eds. *Nuclear Learning in South Asia: The Next Decade* (Monterey, CA: Naval Postgraduate School, 2014) pp. 16-34; Deepa M. Ollapally, "Mixed Motives in India's Search for Nuclear Status," *Asian Survey*, 41, 6 (2001), pp. 925–942.

Historical Background

At the time of India's independence in 1947, the predominant elite view on nuclear weapons was shaped by the experience of the national movement and the Cold War. Mahatma Gandhi's deeplymoral rejection of the new military technology was echoed by Prime Minister Jawaharlal Nehru and his successors, including Indira Gandhi, who was in other ways a quintessential realist willing to use power for national security ends.[2]Nevertheless, the door to possible nuclear capability was not shutby Nehru and was gradually opened wider by his successors. Work on the technology continued under Lal Bahadur Shastri. Though Mrs. Gandhi carried out a single test in 1974 and refrained from building a nuclear arsenal thereafter,she also launched a missile programme and preparations for future nuclear tests were made under her and later prime ministers. A turning pointcame with the conduct of a series of tests in 1998 under Prime Minister Atal Bihari Vajpayee, who declared Indian nuclear doctrine to be "minimum credible deterrence."[3] Once the line had been crossed, the building of an arsenal and its organizational requirements proceeded at a steady pace, which continues today.

In 2002, the *Bulletin of the Atomic Scientists* estimated that India possessed 30-35 warheads in its nuclear armoury.[4] By 2022, the *Bulletin*assessed the number as having grown to about 160.[5] In 2002, Indian delivery vehicles were limited to just two aircraft (the Russian MiG-27 and the British Jaguar) and a single short-range missile, the Prithvi I.The Agni I and Agni II medium-range missiles were then under development.[6]Two decades later, India's delivery vehicles included 3 types of aircraft, a wide range of land-basedshort-, medium- and intermediate-range missiles,and a small but growing capability in submarine-launched missiles.[7]The BrahMos supersonic cruise missile (officially a conventional weapon, but capable of carrying nuclear warheads), and now carried by land-, air-and sea-basedlaunch vehicles, was also introduced.In addition, a number of other advanced weapons systems under development include missiles with much longer ranges, multiple independently targeted re-entry vehicles (MIRV) technology,missile defence systems, and hypersonic weapons, including a hypersonic version of the BrahMos.While these may be seen as representing substantial growth, one must keep in mind that India has (so far) not seriously tried to catch up with China, which has a much larger arsenal that is now growing at a rapid pace without arousing much alarm in New Delhi.[8]

The process of nuclear modernization carries a number of associated costs and gains. These are outlined below.

Challenges Relating to Nuclear Modernization

The predominant difficulty with respect to nuclear modernization involves its intellectual foundation. So far, therequirements of effective nuclear deterrence remain unclear in India and elsewhere.There has been considerable debate amongIndian experts on nuclear strategy over what "minimum

[2] Rajesh M. Basrur, "Nuclear Weapons and Indian Strategic Culture," *Journal of Peace Research*, 38, 2 (2001), pp. 181-198.
[3] Prakash Nanda, "PM Unveils Doctrine of Minimum Credible Deterrence," *Times of India*, August 5, 1998, p. 1.
[4]"India's Nuclear Forces, 2002," *Bulletin of the Atomic Scientists*, 58, 2 (2002), pp. 70-72, at p. 70. Subsequently, the more common usage became "credible minimum deterrence."
[5]Hans M. Kristensen and Matt Korda,"Indian Nuclear Weapons, 2022,"*Bulletin of the Atomic Scientists*, 78, 4 (2022), pp. 224-236.
[6]"India's Nuclear Forces, 2002," at p. 70.
[7]Kristensen and Korda,"Indian Nuclear Weapons, 2022,"Table 1, p. 225.
[8] Hans M. Kristensen, Matt Korda, Eliana Johns and Mackenzie Knight, "Chinese Nuclear Weapons, 2024," *Bulletin of the Atomic Scientists*, 80, 1, (2024), pp. 49-72.

deterrence" actually means and whether it is based on a cohesive set of ideas.[9]The standard view of minimum deterrence is that the bottom line is the possession of minimal "second-strike capability," i.e. the minimumcapacityto withstand an adversary's first strike and retaliate sufficiently strongly to cause unacceptable damage to the attacker.For a minimalist, this does not mean the possession of large and highly sophisticated forces – central toCold War orthodoxy – which produced a confrontation involving tens of thousands of nuclear weapons between the United States and the Soviet Union. In practice, there is considerable ambiguity about the viable requirements for a minimum deterrence posture.

Soon after the 1998 tests, Indian thinking, encapsulated in an interview given by Jaswant Singh, a cabinet minister in Vajpayee's government, was that more nuclear tests were not required; nuclear weapons need not be deployed (but could be kept in a disassembled state for safety reasons); a few weapons would suffice; there was no need for a triad of land-, air- and sea-based platforms; and there was no question of nuclear "warfighting" with tactical, low-yield weapons.[10]Over time, however, there has been a schism in Indian thinking and practice. On one hand,there have been no tests, no weapons deployments and no serious interest in warfighting; on the other, the number of weapons – both warheads and delivery systems – has been steadily rising; a triad of platforms has been developed; and, as noted above, an increasingly sophisticated arsenal is under development.[11]Notably, the language employed even by minimalists is drawn from Cold War discourse, in which "second-strike capability" and the importance of "credibility" to convey both national capacity and will are central. And that borroweddiscourse was one that produced more than 64,000 warheads and an array of weapons by the mid-1980s. Unfortunately, the mismatch has been barely understood and the pressure to continually enhance capability is likely to remain unrelenting.Occasional calls for more testing and tactical weapons for nuclear warfighting are aired from time to time.

One consequence of an ever-expanding nuclear armoury is rising cost. As with other nations, India has an opaque and secretive budgetary approach to nuclear weapons and the financial outlay remains very hard to assess. In part, this is because there is no costing firewall between nuclear and conventional weapons: many weapons are dual-capable and there is similar ambiguity with respect to military and civilian staff employed in the two sectors. One estimate made in 2003 was that, over the following decade, India would spend some 0.5 per cent of its gross domestic product (GDP) on nuclear arsenal, and this was said to be a conservative estimate that left out a number of factors.[12]In another assessment, India in 2022 spent $2.7 billion on nuclear weapons.[13]While these figures are not reliable, they give us some idea as to the scale of expenditure on nuclear weapons. Rising expenditure on a growing arsenal is likely to involvea degree of competitive arms racing and a wasteful build-up that does not add to national security, as the Cold War experience has shown.

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[9]See, e.g. Frank O'Donnell and Debalina Ghoshal, "Managing Indian Deterrence: Pressures on Credible Minimum Deterrence and Nuclear Policy Options," *Nonproliferation Review*, 25, 5-6 (2018), pp. 419-436; "Rajesh Rajagopalan, India's *Nuclear Doctrine Debate*, Washington, DC: Carnegie Endowment for International Peace, June 2016 < https://carnegieendowment.org/2016/06/30/india-s-nuclear-doctrine-debate-pub-63950>.

[10]"India Not to Engage in A Nuclear Arms Race: Jaswant," (Interview), *Hindu*, November 29, 1999, p. 14.

[11]Rajesh Basrur, *Subcontinental Drift: Domestic Politics and India's Foreign Policy* (Washington, DC: Georgetown University Press, 2023), pp. 111-147.

[12] Urvashi Sarkar, "What's Known—and Not Known—about India's Nuclear Weapons Budget," *Bulletin of the Atomic Scientists*, November 2, 2021 <https://thebulletin.org/2021/11/whats-known-and-not-known-about-indias-nuclear-weapons-budget/> [accessed on 2-3-24].

[13]*Wasted: 2022 Global Nuclear Weapons Spending*, International Campaign to Abolish Nuclear Weapons, Geneva, 2022, p. 5.

What the process of enhanced arms acquisition does not do is eliminate a source of constant tension that arises from the "stability-instability paradox."[14]In brief, the paradox applies when nuclear rivals have an incentive to engage in low-level armed conflict because they know neither side can afford to fight a full-scale war for fear of escalation over the nuclear threshold.Thus India and its two major rivals have been involved in recurrent confrontations post-nuclearization. India-China clashes have occurred repeatedly over their disputed border, with major incidents in 2017 and 2020 (the latter still to abate); while India-Pakistan crises over Kashmir have occurred regularly, with peaks in 1999, 2001-02, 2016 and 2019. The key point is that nuclear modernization has not reduced this tension, but has sharpened a rivalry that shows no sign of dissipating. On the contrary, as will be shown below, the growing complexity of the technologies involved has made thesealtercationsincreasingly risk laden.

One area of particular concern that has received inadequate attention is the overlap between nuclear and conventional weapons. To be sure, Indian analysts have recognized the problem of escalation across the nuclear threshold.[15]The phenomenon can occur across a range from gradual and intermittent to extremely rapid intensification,the last sometimes called "wormhole" or "catalytic" escalation.[16] But it remains under-appreciated in the Indian strategic studies literature.[17]For instance, there is the problem of "entanglement," when there is no clear line between conventional and nuclear weapons and targets.[18]Command and control centres may be of a dual nature, as may aircraft and missiles. Similarly, unintended targeting of nuclear assets may occur when weapons are misfired or inaccurate. In a prominent instance of the risk involved,a BrahMos cruise missile accidentally took off from western India and flew about 160 km into Pakistan before (fortunately) crashing harmlessly.[19]The positioning of short-range missiles close to borders keeps this risk in the forefront.

A third area on which questions might well be asked (but have rarely been) is the utility of the undersea deterrent. The received wisdom among strategic thinkers in India (indeed, everywhere) is that submarine-based nuclear weapons are the *sine qua non* of effective deterrence as they offer assured second-strike capability. Hence, it is often said that Indian capability, which is still in infancy with respect to SLBMs, is as yet incomplete.[20] The argument is questionable. It is a commonplace

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[14]Snyder, Glenn H. "The Balance of Power and the Balance of Terror," in Paul Seabury, ed. *The Balance of Power* (San Francisco: Chandler, 1965); Michael Kreponand Chris Gagné, eds. *The Stability-Instability Paradox: Nuclear Weapons and Brinkmanship in South Asia*. Washington, DC: Henry L. Stimson Center, 2001.

[15]G. D. Bakshi, *Limited Wars in South Asia: Need for an Indian Doctrine*(New Delhi: KW Publishers, 2010), pp. 152-156; Prakash Menon, *The Strategy Trap: India and Pakistan Under the Nuclear Shadow*(New Delhi: Wisdom Tree, 2018), pp. 173-177; V.R. Raghavan, "Limited War and Nuclear Escalation in South Asia,"*Nonproliferation Review* 8, 3 (2001),pp. 82–98.

[16]Rebecca Hersman, "Wormhole Escalation in the New Nuclear Age," *Texas National Security Review* 3, 3, (2020), pp. 90–109; James Johnson, "'Catalytic Nuclear War' in the Age of Artificial Intelligence & Autonomy: Emerging Military Technology and Escalation Risk Between Nuclear-Armed States," *Journal of Strategic Studies*, (2021), pp. 1–41, doi:10.1080/01402390.2020.1867541.

[17] Rajesh Basrur and Wu Shang-Su,"India's Conventional Strategy in a Nuclear Environment: A Neglected Link," *Defence Studies*23, 3 (2023), pp. 457-476.

[18] James M. Acton, Li Bin, and Tong Zhao, *Reducing the Risks from Nuclear Entanglement* (Washington, DC: Carnegie Endowment for International Peace, September 2018).

[19]Christopher Clary, "The Curious Case of the Accidental Indian Missile Launch." *War on the Rocks*, March 17, 2022<https://warontherocks.com/2022/03/the-curious-case-of-the-accidental-indian-missile-launch/>.

[20]Rahul Jaybhay, "The AUKUS Deal and India's Submarine Dilemma," *Diplomat*, April 14, 2023<https://thediplomat.com/2023/04/the-aukus-deal-and-indias-submarine-dilemma/>;Girish Luthra, *The Sea Leg of India's Nuclear TriadPost-Pokhran II* (New Delhi: Observer Research Foundation, May 11,

notion that assured deterrence capacity requires the possession of nuclear-powered submarines (SSBNs) armed with missiles carrying nuclear warheads or submarine-launched ballistic missiles (SLBMs). In fact, in *no* crisis between nuclear powers hasdeterrence been backed by SLBMs.Yet, we do know that, even in the most intense confrontations between nuclear-armed states,deterrence always works to prevent war.Moreover, strategic restraint has invariably been evident whenever *any* kinds of nuclear weapons are present during a confrontation worldwide. Needless to say, this clearly applies to the India-China and India-Pakistan cases.In short, the pursuit of undersea nuclear capability can be arguably regarded as a needless and expensive distraction. It is also a risky one. At sea, red lines are rarely clear because borders are literally liquid; because submarines regularly practise hostile actions like "stalking"; and submarine accidents involving hostile navies occur regularly.[21]Furthermore, it is by no means guaranteed that even robust command and control systems will always ensure that nuclear weapons-carrying submarines receive orders from strategic commanders; or, for that matter, in this age of advanced cyber technology, that hackers will not transmit fake orders to submarine commanders. On this more below.And finally, in the race between stealth and detection technologies, the advantage swings periodically between the two and there is no certainty that the latter will not outweigh the former in times to come.[22]

A fourth difficulty forIndia's nuclear modernization is the rapid onset of technological complexity that is under way. The armed forces have given considerable attention to the incorporation of new technologies. These include cyber technology, artificial intelligence (AI), space, unmanned craft, hypersonic vehicles, directed energy weapons,and missile defence. For reasons of space, the first three are focused on below.

In 2015, the government launched the "Digital India" project and defence applications were incorporated in a nation-wide Spectrum Optical Fibre Project.[23]The army has focused on diverse aspects of cyber technology, including intelligence and offensive operations.[24]In August 2021, the government announced in Parliament that it had created a Defense Cyber Agency and in December 2021, the army announced the establishment of a Quantum Lab at Military College of Telecommunication Engineering (MCTE)at Mhow. While the army did not provide details, it is well known that the technology has a wide range of military applications pertaining to communications, electronic warfare, radar, and missile navigation.[25]

A broad IndiaAI Mission to establish an AI infrastructure was announced in March 2024. Though no mention was made of a defence dimension, that is presumed to be part of the overall vision.[26]The

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2023);Abhijit Singh, *India's Nuclear Triad: Still A Work in Progress* (New Delhi: Observer Research Foundation, May 10, 2023)<https://www.orfonline.org/expert-speak/indias-nuclear-triad-still-a-work-in-progress/>.

[21]Christopher Tingle, "Submarine Accidents: A 60-Year Statistical Assessment," *Professional Safety*, 54, 9 (September 2009, pp. 31-39.

[22] Andrew Futter, "Disruptive Technologies and Nuclear Risks: What's New and What Matters," *Survival*, vol. 64, 1 (February–March 2022), pp. 99–120; Mizuho Kajiwara,"Maritime Security and Underwater Surveillance Technology: Lessons from the Cold War," *Indo-Pacific Outlook*, 1, 3 (January 2024), pp. 1-7.

[23]J. P. S. Bains, *Digital India, Digital Army*(New Delhi: Centre for Land Warfare Studies, July 10, 2015)<https://archive.claws.in/1405/digital-india-digital-army-t-s-bains.html>.

[24]*Pinnacle*. "Special Issue on Employment of Offensive Cyber As A Multiplication Tool for Defensive and Offensive Operations by Indian Army" (2021). <https://indianarmy.nic.in/Site/FormTemplete/frmTempSimple.aspx?MnId=SRfQpeSk3lNWyAd3wDt2QqArOTqfNI8d3UaVg+dZagA=&ParentID=SQRNv69OiHnv6xPzZG4isw==>.

[25]Michal Krelina, "EPJ Quantum Technology." *EPJ Quantum Technology*, 8, 1 (2021), doi:10.1140/epjqt/s40507-021-00113-y. Accessed on August 8, 2022.

[26] Press Information Bureau (Government of India), "Cabinet Approves Over Rs 10,300 Crore for IndiaAI Mission, Will Empower AI Startups and Expand Compute [sic] Infrastructure Access," March 7, 2024

armed forces have also been developing capacity with respect to AI.[27]AI applications under development at MCTE include Autonomous/Unmanned/Robotics systems; Block Chain-based Automation; Command, Control, Communication, Computer and Intelligence, Surveillance and Reconnaissance; Cyber Security; Human Behavioural Analysis; Intelligent Monitoring Systems; Lethal Autonomous Weapon Systems; Logistics and Supply Chain Management, and Operational Data Analytics.[28]With respect to space, India's development of defence space capability has in the past tended to lag.[29] The government has now sought to boost the role of the private sector.It has also inaugurated an anti-satellite(ASAT) programme: its first and successful ASAT test was conducted in 2019. The Indian Army has established a satellite-based network of some 200 stationary terminals, 80 mobile terminals on ground-based transport, and an uncertain number of individually carried terminals[30]

While interest in the new technologies is rising, not much attention has been paid to their nuclear dimension.[31]A significant risk applies to the possibility of cyber attacks on the nuclear infrastructure, including civilian nuclear power plants, by adversary states or non-state actors.Cyber attacks can dislocate warning systems,disruptwider command and control systems, or be misinterpreted as attacks on the nuclear weapons infrastructure, particularly given that it is hard to separate conventional and nuclear systems.Difficulties associated with a decision on how to respond to a potential cyber attack include lack of clarity on the source of attack, false alarms, misinterpretation of electronic signals and, above all, the potential for wormhole escalation. With regard to AI-driven autonomous weapons systems, they will tend to undermine human decisions by subjecting them to automated responses generated by algorithms, or at least to problems of misperception and accident associated with such systems.[32]Third parties could employ "AI-driven adversarial inputs, data-poisoning attacks, and audio and video manipulation to create escalatory effects."[33]A problem relating to space is the commingling of conventional and nuclear weapons infrastructures, notably

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<https://pib.gov.in/PressReleasePage.aspx?PRID=2012375>. A brief mention of the defence aspect was made in an earlier government report. See Ministry of Electronics and Information Technology, Government of India, *India AI 2023*, October 2023 <https://www.meity.gov.in/writereaddata/files/IndiaAI-Expert-Group-Report-First-Edition.pdf>.

[27] Kartik Bommakanti, "AI in the Indian Armed Services: An Assessment." CLAWS Journal, 14, 1(2021), pp. 101–117; Shammi Raj,*Artificial Intelligence in the Armed Forces*(New Delhi: United Service Institution of India: August 27, 2020),<https://usiofindia.org/publication/cs3-strategic-perspectives/artificial-intelligence-in-the-armed-forces/?sf_paged=5>.

[28] Press Information Bureau (Government of India), "Raksha Mantri [= Defence Minister] Launches 75 Artificial Intelligence Products/Technologies During First-Ever 'AI in Defence' Symposium & Exhibition in New Delhi; Terms AI as a Revolutionary Step in the Development of Humanity," (July 22, 2022),<https://pib.gov.in/PressReleasePage.aspx?PRID=1840740>.

[29]Vaibhav Agrawal, "India Beyond Earth: India's Status in Space Military Race," *FinancialExpress*(July 4, 2022),<https://www.financialexpress.com/defence/india-beyond-earth-indias-status-inspace-military-race/2582187/>; Namrata Goswami, *Indian Space Program and Its Drivers: Possible Implications for the Global Space Market* (Paris: French Institute of International Relations, 2022).

[30]Ajay Banerjee, "Army Exercise to Test Satellite-Based System." *Tribune*, August 6, 2022,<https://www.tribuneindia.com/news/nation/army-exercise-to-test-satellite-based-system-419238>.

[31] For relatively sketchy exceptions, see Manoj M. Naravane, *Shifting Domains of Warfare*. Manekshaw Paper, 96 (New Delhi: Centre for Land Warfare Studies, 2021);Rakesh Sharma*, Multi-Domain Warfare, Cross-Domain Deterrence*(New Delhi: Centre for Land Warfare Studies, 2020). For a closer look, seeB. Poornima, "Cyber Threats and Nuclear Security in India." *Journal of Asian Security and International Affairs*, 9, 2 (2022), pp. 183–206; Petr Topychkanov, ed. *The Impact of Artificial Intelligence on Strategic Stability and Nuclear Risk*(Stockholm: Stockholm International Peace Research Institute, 2020).

[32]Michael C. Horowitz, "When Speed Kills: Lethal Autonomous Weapon Systems, Deterrence and Stability," *Journal of Strategic Studies*, 42, 6 (2019), pp. 764–788.

[33]Mark Fitzpatrick, "Artificial Intelligence and Nuclear Command and Control," *Survival*, 61, 3 (2019), pp. 81–92.

with respect to early warning systems.[34] ASAT systems are vulnerable to accidents, false warnings, and disruption by cyber attack, all compounded by the possibility of misperception. As we know, non-kinetic interference in the functioning of satellites occurs regularly.[35]These could be interpreted, especially during times of crisis, as attacks on the dual-use command and controlnuclear infrastructure. This applies in particular to India's dual-use satellite infrastructure.[36]

Gains from Nuclear Modernization

The preceding section has highlighted some of the complexities and difficulties associated with nuclear modernization. But there is a positive side as well.The bottom line is that, while nuclear weapons are a source of great risk, they are also a source of great security, even if not unproblematically so. A world without nuclear weapons may be an extremely insecure one where the use of new technologically advanced conventional weapons could bring unprecedented destruction. In a world with nuclear weapons, arguably, the risk of holocaust will always be present, but that risk compels us to try and avoid major war. For policy makers, in particular, it is a Hobson's choice: either way the potential costs are huge. It is unsurprising that many states that have the capacity to go nuclear and feel threatened by the weapons of others have done so. And quite a few are either seeking actively to cross the line or have hedged their bets. In short, the dilemma posed by nuclear weapons is thatthey do not allow states to escape insecurity entirely, but that possessing them does help avoid nuclear blackmail or, worse, attack. From this perspective, it would appear that nuclear modernization is an imperative if it can help resist offensive actions by nuclear adversaries.From India's viewpoint, given the threat posed by two nuclear-armed states, China and Pakistan, with whom its borders are contested, and with whom there is a history of war and periodic crises, it would seem irresponsible to abjure nuclear weapons altogether and the associated changes in dual-use technology such as cyber and AI. It follows that a degree of nuclear modernization, including careful attention to the complexities introduced by recent technological developments, are necessary. To be sure, this does not eliminate the problem of the stability-instability paradox, but it can still be viewed as a better alternative to abandoning the fundamental requirements of security, i.e. deterrent nuclear forces.

The use of the relatively new technologies referred to aboveoffers numerous benefits vis-à-vis national security.First,command, communications and control can be optimizedwith advancedcyber technology, which is particularly important with regard to the taking and execution of launch decisions and, by the same token, prevention of mala fide or erroneous firing of weapons, and for optimal internal communication. Ultimately, a robust cyber capability is vital for obtaining confidence that a defence apparatus is reliable.[37]Maintaining a high level of training for both cyber defence and

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[34] James M. Acton, "Escalation Through Entanglement: How the Vulnerability of Command-And-Control Systems Raises the Risks of an Inadvertent Nuclear War," *International Security*, 43, 1 (2018), pp. 56–99; Mariel John Borowitz, Lawrence Rubin, and Brian Stewart, "National Security Implications of Emerging Satellite Technologies," *Orbis*, 64, 4(2020), pp. 515–527.

[35] John Borrie, "Nuclear Risk and the Technological Domain: A Three-Step Approach," in Wilfred Wan, ed. *Nuclear Risk Reduction: Closing Pathways to Use* (Geneva: United Nations Institute for Disarmament Research, 2020), pp. 71–92.

[36]Lauren J. Borja and M. V. Ramana, "Command and Control of India's Nuclear Arsenal." *Journal for Peace and Nuclear Disarmament*, 3, 1 (2020), pp.1–20.

[37]Roger Darby, Lorraine Dodd and Jeremy Hilton, "Cyber Security and Knowledge Management," in Laura R. Cleary and Roger Darby, eds. *Managing Security: Concepts and Challenges* (London: Routledge, 2021), pp. 140-159.

attack capability is essential to this end.[38]Artificial intelligence provides for better and faster optimization of large quantities of data. For instance, AI can integrate enormous quantities of data obtained from satellite, human and other sourcesto assess an enemy's capability;design, manufacture and maintain complex weapons systems;respond to targeting challenges; support verification and arms control; and provide a host of other applications.[39]Space technology, growing in value and yet restricted to states that have the technological and financial capacity to possess them, has an array of uses, chief among them communication, navigation, non-intrusive intelligence gathering, targeting, and arms control verification.[40]

These advantages apply directly to the nuclear weapons infrastructure, but more generally to related defence and civilian infrastructures. Importantly, keeping pace with technological change carries the advantage of building capacity that anticipates forthcoming technological revolutions that one cannot afford to build on as a late starter.

Another distinct gain stemming from nuclear modernization – one that is often ignored by critics –is influence in the international system. While there are certainly other sources of influence such as economic power or national ideology,it remains undeniable that, in a world wherein military power is still a valuedinstrument of national image, advances in militarycapacity are a source of national prestige carrying considerable weight.[41]India under Jawaharlal Nehru laid claim to being an influential power, but it lacked the ballast of military power undergirded by economic growth and the balloon burst when it failed to defeat Pakistan in 1947-48 and 1965 and lost badly to China in 1962.[42] Even when there was much talk of India's rise after the spurt in its economic growth in the early 1990s, it was widely labelled a rising economy –an "emerging market" or "emerging economy."[43] It was only after its 1998 nuclear tests that it began to be seen as a "rising power."[44]

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[38]Darko Galinec,Darko Možnik and Boris Guberina, "Cybersecurity and Cyber Defence: National Level Strategic Approach," *Automatika*, 58, 3 (2017) pp. 273-286; Muhammad Mudassar Yamin and Basel Katt, "Use of Cyber Attack and Defense Agents in Cyber Ranges: A Case Study," *Computers & Security*, 122 (November 2022), <https://doi.org/10.1016/j.cose.2022.102892>.

[39]Thomas Reinhold and Niklas Schörnig, eds. *Armament, Arms Control and Artificial Intelligence: The Janus-faced Nature of Machine Learning in the Military Realm* (Cham, Switzerland: Springer, 2022); Akshat Upadhyay, *Likely Impact of Emerging Technologies on India's Nuclear Arsenal* (New Delhi: Observer Research Foundation, May 10, 2023) <https://www.orfonline.org/expert-speak/likely-impact-of-emerging-technologies-on-indias-nuclear-arsenal> (accessed on 7-3-24).

[40]Michael P. Gleason and Peter L. Hays, *A Roadmap for Assessing Space Weapons* (Arlington, VA: Center for Space Policy and Strategy, 2021); Jon R. Lindsay and Erik Gartzke, "Politics by Many Other Means: The Comparative Strategic Advantages of Operational Domains," *Journal of Strategic Studies*, 45, 2 (2020), pp. 1-34.

[41]Joshua Freedman, "Status Insecurity and Temporality in World Politics." *European Journal of International Relations*, 22, 4 (2015), pp. 797–822; T. V. Paul, Deborah Welch Larson, and William C. Wohlforth, eds. *Status in World Politics* (New York: Cambridge University Press, 2017).

[42]Rajesh Basrur and Kate Sullivan de Estrada, *Rising India: Status and Power* (New York: Routledge, 2017); Baldev Raj Nayar and T. V. Paul, *India in the World Order: Searching for Major-Power Status* (Cambridge: Cambridge University Press, 2003).

[43]Barry Eichengreen, Poonam Gupta and Rajeev Kumar, eds. *Emerging Giants: China and India in the World Economy* (New York: Oxford University Press, 2010); Aamir Firoz Shamsi, Iqbal A. Panhwar, Badar Iqbal, and Khizar Cheema. 2014. "India as an Emerging Economy," *Transnational Corporations Review*, 6, 1 (2014), pp. 15–25.

[44]Stephen P. Cohen, *India: Emerging Power* (Washington, DC: Brookings Institution Press, 2001); Manjeet S. Pardesi, "Is India a Great Power? Understanding Great Power Status in Contemporary International Relations," *Asian Security*, 11, 1 (2015), pp. 1–30.

Noticeably, only thereafter did the United States and other major powers begin to cultivate India for strategic purposes. And only then did India begin to acquire seats at multiple global institutional tables such as the BRICS (Brazil, Russia, India, China and South Africa) grouping, the Missile Technology Control Regime, and the Quad. From this perspective, maintaining a certain standard of nuclear military power even as it exercises strategic restraint contributes to its influence in world politics. The prestige it has obtained is not simply empty image, but gives it some clout in an on-going process of rising influence that helps serve its interests. Nothing illustrates this more than the India-US nuclear agreement of 2008, whichtransformed India from a virtual pariah in the eyes of the nuclear nonproliferation regime to a "responsible nuclear power" after that date.[45]As affirmed byCondoleezza Rice, President George W. Bush's National Security Advisor, Bush now saw India as "a natural fit for US strategic interests"– ultimately, a long-term partner in global stability and a counter to China.[46]The degree to which the United States was willing to override its nonproliferation goals to build a strategic partnership with India reflects the new significance of India as a nuclear power. Washington not only amended its own domestic nonproliferation law, but persuaded other members of the Nuclear Suppliers Group to open up civil nuclear trade with India – a policy change which, by exempting the latter's military reactors from international oversight, indirectly recognized India as a nuclear power.

This brief history of the dynamics driving India's crossing of the nuclear Rubicon offers an important insight into the launching of India's rise to the status of a major power. While other factors such as economic growth have accounted for an important part of the story, it is evident that nuclear weapons have played a major role. Having crossed this strategic milestone, India can scarcely afford not to upgrade its capabilities: nuclear modernization needs to be sustained, though there will always be debates about how much.

Conclusion

The preceding pages have shown the difficulties associated with nuclear modernization as well as the rewards it has brought.From the policy maker's point of view, the possession ofnuclear weapons brings out the security dilemma that is common to insecure states.[47] On the one hand, nuclear capabilities provide basic security from nuclear attack and therefore offer a foundation for national survival; on the other, nuclearization has producedhigh levels of tension with both China and Pakistan and resulted in the occurrence of repeated border criseswith both.At bottom, though, the option of giving up nuclear weapons only sharpens the dilemma: it would very likely leave India subject to inimical pressures from its adversaries.

This raises a related question: does nuclear *modernization*per se produce another kind of security dilemma?While buttressing India's deterrence forces and therefore its security, nuclear modernization does inevitably lead to greater tensions with both China and Pakistan. At the same time, it could be argued that improvements in nuclear capability are unavoidable if India is to avoid falling behind its adversaries and become vulnerable to strategic pressures as a result. Either way, the element of insecurity is inescapable. What then might be done about this dilemma?

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[45]Dinshaw Mistry, *The US–India Nuclear Agreement: Diplomacy and Domestic Politics* (Delhi: Cambridge University Press, 2014); Harsh V. Pant, *The US–India Nuclear Pact: Policy, Process, and Great Power Politics* (New Delhi: Oxford University Press, 2011).

[46]Condoleezza Rice, *No Higher Honor: A Memoir of My Years in Washington* (New York: Crown, 2011), p. 129.

[47]Robert Glaser, "The Security Dilemma Revisited," *World Politics*, 50, 1 (October 1997), pp. 171-201; Robert Jervis, "Cooperation under the Security Dilemma," *World Politics*, 30, 2 (January 1978), pp. 167-214.

Perhaps the only practicable way to minimize the dilemma is to adhere to a minimalist approach to nuclear strategy. Already, a measure of nuclear restraint that reins in the risk of warhas been practised by India as well as its adversaries by keeping nuclear weapons in a disassembled state, which retains deterrence capacity, butis also less threatening. This lengthens the time frame between a crisis and the actual launch of a weapon. The notion that a high level of readiness is essential to avoid vulnerability – a staple of Cold Wararguments –does not apply, indeed, has never applied. Nor is it necessary to possess the sea leg of the so-called triad for attaining assured second-strike capability. The idea of being secure from the threat of a "surgical strike" is far-fetched. In 2006, when a US-North Korea crisis was brewing, Pyongyang was believed to have just two nuclear warheads, but Washington thought it prudent not to attempt a surgical strike. An unnamed American official pointed to the risk: "what good is a strike if it leaves their nuclear capability untouched?"[48] In short, it does not take much to deter. This is also a point to keep in mind when there is pressure to build more and "better" weapons.

There is something to be said for keeping up with the nuclear Joneses. If everyone believes that a larger and more sophisticated arsenal brings greater security, then – to the extent that it is feasible – modernization can be said to have a greater deterrent effect. Against this, an open-ended approach runs the risk of becoming a maximalist one, so the outcome in the long run will be more risk and needlessly highfinancial outlay. Optimizing the trade-off between the security and strategic influence obtained from nuclear modernization and the potential risks and budgetary costs associated with it lies in ensuring the balance is always in favour of lower risk to survival. A minimalist approach is therefore a must.

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[48]David E. Sanger,"Don't' Shoot. We're Not Ready,"*New York Times*, 3 August2006<https://www.nytimes.com/2006/06/25/weekinreview/25sanger.html>.