Assessment of India's Nuclear Security Architecture

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Abstract

This paper is an attempt to assess Indian nuclear security architecture in the light of recurrent Indian nuclear security incidents and their impact on national regional and global non-proliferation efforts. India is one of the significant global nuclear energy markets for Russia and US alike. Nevertheless, nuclear safety and security incidents including uranium thefts in India have increased concerns regarding Indian nuclear security architecture. The study utilizes International Nuclear Security Framework to assess the Indian nuclear security architecture. This research aims to analyze Indian nuclear safety and security measures by exploring Indian uranium theft incidents, nuclear security lapses and over all gaps in Indian nuclear security architecture. Through this analysis, the study explores Indian nuclear credentials and its adherence to global nuclear nonproliferation standards and norms. This study further investigates how such incidents impact Indian nuclear credentials vis-à-vis global nuclear governance and provides recommendations for India to enhance its nuclear security infrastructure to reduce the risk of such incidents thereby, enhance its nuclear non-proliferation credentials.

Keywords: Nuclear Safety, Nuclear Security, Indian Nuclear Program, Uranium Theft

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Introduction

As an important player in the global nuclear energy market, India continues to modernize its nuclear program for its civilian and military purposes. Nevertheless, recent nuclear security incidents including uranium thefts have raised concerns regarding India's nuclear security architecture. These incidents not only highlight inadequacy of Indian nuclear security infrastructure, but also raise concerns regarding its adherence to international nuclear non-proliferation norms. According to the International Atomic Energy Agency (IAEA), nuclear security is *"Prevention of, detection of, and response to, criminal or intentional unauthorized acts involving or directed at nuclear material, other radioactive material, associated facilities, or associated activities."*[1]

To understand the role of IAEA in nuclear security and India's nuclear security architecture, multiple studies have been conducted. Carmona outlines the IAEA's role in assisting member states to prevent and respond to nuclear terrorism through a comprehensive global nuclear security program.[2] Donohue highlights advancements in IAEA safeguards, particularly the use of environmental sampling and analysis, which strengthen the detection of undeclared nuclear activities.[3] Fedchenko examines the challenges faced by the IAEA during armed conflicts, such as the attacks on nuclear facilities in Ukraine.[4] Uadiale explores the IAEA's contributions to international diplomacy, highlighting its role in promoting sustainable nuclear security. Despite challenges, the agency has been instrumental in fostering peace and mitigating threats posed by non-state actors.[5] Singh discusses the IAEA's role in facilitating peaceful uses of nuclear technology while enforcing safeguards to prevent proliferation.[6] Langlois examines the IAEA's

[1] IAEA, "IAEA Safety and Security Series," Official Website, IAEA, 2023, https://nucleus-apps.iaea.org/nss-oui/Content/Index?CollectionId=m_8810942f-6fa7-4b88-a185-0c7005431b32&type=PublishedCollection.
[2] United Nations Office for Disarmament Affairs, "IAEA: Assistance in Nuclear Security," United Nations Office of Disarmament Affairs (UNODA) Occasional Papers (UN, 2008), 121–45.
[3] D.L Donohue, "Strengthening IAEA Safeguards through Environmental Sampling and Analysis," *Journal of Alloys and Compounds* 271–273 (June 1998): 11–18, https://doi.org/10.1016/S0925-8388(98)00015-2.
[4] Vitaly Fedchenko, "Nuclear Security During Armed Conflict: Lessons From Ukraine" (Stockholm International Peace Research Institute, 2023), https://doi.org/10.55163/ZZSP5617.
[5] Martin Uadiale, "International Atomic Energy Agency (Iaea) And The Diplomacy Of Sustainable International Nuclear Security," 2011, https://www.semanticscholar.org/paper/INTERNATIONAL-ATOMIC-ENERGY-AGENCY-(IAEA)-AND.
[6] A. Singh, "IAEA and Cooperation in Nuclear Technology," 2012, https://www.semanticscholar.org/paper/IAEA-and-Cooperation-in-Nuclear-Technology-Singh/f5e92c051325a174a758326448d6341607405c4c?utm_source=consensus.

response to the Fukushima disaster, highlighting the development of a comprehensive action plan that incorporates safety reviews and emergency preparedness measures.[7]

Deolalikar highlights that safety in India's nuclear power plants (NPPs) is of paramount importance and governed by strict regulations, including radiological protection for workers and the public, regular surveillance, and comprehensive emergency preparedness plans.[8] Moses Raj examines the implications of the Additional Protocol ratified by India, which separates civilian and military nuclear facilities.[9] Joshi with co-authors focus on the core safety features of Indian nuclear reactors, particularly heavy water reactors, in extreme conditions like tsunamis.[10] Neeraj examines the cybersecurity framework for Indian nuclear facilities, emphasizing vulnerabilities to cyberattacks.[11] Thomas and Gupta analyze India's nuclear policy and its implications for national and regional security.[12] They highlight the challenges in balancing nuclear ambitions. Raj et al. discuss India's radioactive waste management practices, emphasizing the development of innovative processes for waste treatment and disposal.[13]

Previous studies discuss multiple dynamics of the IAEA nuclear security framework. Furthermore, authors have also discussed different aspects of Indian nuclear security architecture. However, as these incidents are continuously occurring, it demands a new study in light of new incidents to understand the current status of Indian nuclear safety and security measures. In this paper, gaps and systemic weaknesses in Indian nuclear security architecture are analyzed through these incidents, which can have domestic and global repercussion through either illicit trafficking of dangerous materials or nuclear terrorism. The study is also an attempt to investigate the impact of such gaps in Indian nuclear security credentials within global nuclear non-proliferation

[7] L. Langlois, "IAEA Action Plan on Nuclear Safety," *Energy Strategy Reviews* 1 (2013): 302–6, https://doi.org/10.1016/J.ESR.2012.11.008.
[8] R Deolalikar, "Safety in Nuclear Power Plants in India," *Indian Journal of Occupational and Environmental Medicine* 12, no. 3 (2008): 122, https://doi.org/10.4103/0019-5278.44693.
[9] Moses Raj G S, "Nuclear Safety in India: The Balancing Rope of Domestic Energy Demand and International Safeguards Regime," *Jindal Journal of International Affairs* 4, no. 1 (October 1, 2016): 60–84, https://doi.org/10.54945/jjia.v4i1.55.
[10] J B Joshi et al., "Core Safety of Indian Nuclear Power Plants (NPPs) under Extreme Conditions," *Sadhana* 38, no. 5 (October 2013): 945–70, https://doi.org/10.1007/s12046-013-0177-6.
[11] Neeraj B R, "Cybersecurity in Indian Nuclear Facilities," *Electronic Journal of Social and Strategic Studies* 04, no. 03 (2024): 314–38, https://doi.org/10.47362/EJSSS.2023.4302.
[12] Gaurav Kampani, "India's Nuclear Security. Edited by Raju G. C. Thomas and Amit Gupta. Boulder, Colo.: Lynne Rienner Publishers, 2000. 325 Pp. $59.95.," *The Journal of Asian Studies* 60, no. 2 (May 2001): 598–600, https://doi.org/10.2307/2659762.
[13] K. Raj, K.K. Prasad, and N.K. Bansal, "Radioactive Waste Management Practices in India," *Nuclear Engineering and Design* 236, no. 7–8 (April 2006): 914–30.

framework. As the repercussions of any nuclear safety and security incidents do not respect borders, this issue is critical for domestic, regional and global security. The paper also provides recommendations for mitigating any future nuclear risks. If not, such incidents may indicate that India is not a responsible nuclear state. This study utilizes "International Nuclear Security Cooperation framework" that refers to "a system of international agreements, norms, and mechanisms established primarily through the IAEA to prevent the theft, misuse, or proliferation of nuclear materials by facilitating cooperation between nations to enhance nuclear security measures and respond to potential threats, including nuclear terrorism; it includes legally binding instruments like the Convention on the Physical Protection of Nuclear Material (CPPNM) and non-binding guidelines for best practices in nuclear security."

1. International Nuclear Security Cooperation

IAEA is the major international organization which has taken a leading role in dealing with safety, security and peaceful uses of nuclear energy. To counter nuclear risk, IAEA uses a three-part strategy. This includes prevention of non-peaceful use of nuclear material, detection of such non-peaceful use, and proactive and prompt recommendations to United Nations Security Council when such risks are detected. India adheres to IAEA nuclear security guidelines .

The main component of international nuclear security regime is United Nations which provides international infrastructure on nuclear security. The International Convention for the Suppression of Acts of Nuclear Terrorism (ICSANT) – entered into force in 2007 and adopted in 2005–entails protection against attacks on nuclear installations and facilities through domestic criminalization of planning, executing or threatening of nuclear terrorism. India signed as well as ratified ICSANT while including a reservation that "India does not consider itself bound by the provision of Paragraph (1) of Article 23."[14] The article states:

> Any dispute between two or more States Parties concerning the interpretation or application of this Convention which cannot be settled through negotiation within a reasonable time shall, at the request of one of them, be submitted to arbitration. If, within six months of the date of the request for arbitration, the parties are unable to agree on the organization of the arbitration, any one of those parties may refer the dispute to the International Court of Justice, by application, in conformity with the Statute of the Court.

[14] "United Nations Treaty Collection," United Nations, accessed July 25, 2024, https://treaties.un.org/pages/ViewDetailsIII.aspx?src=TREATY&mtdsg_no=XVIII-15&chapter=18&Temp=mtdsg3&clang=_en.

This reservation undermines interstate cooperation and accountability to address nuclear terrorism, thereby decreasing convention's effectiveness to counter nuclear threats.

UN Security Council Resolution 1540 entails the prevention of non-state actors from acquiring weapons of mass destruction (WMD) including their materials, delivery systems and weapons. It is an attempt to criminalize receiving, using, financing or further transferring WMDs to any non-state actors. For this purpose, states are obligated to enforce effective domestic mechanisms for control, accounting, physical protection and border control infrastructure. India submitted 7th report to UNSCR 1540 on 4 August 2023. In the report, India focused on its national framework, legislative measures as well as inter agency framework to comply with UNSC Resolution 1540. Solely internal, domestic and government-led self-regulation may hinder international independent verification and external oversight. This will further create gaps to ensure full compliance with international export control standards regarding WMDs.

The Global Initiative to Combat Nuclear Terrorism (GICNT) is a non-binding voluntary framework aimed at prevention, detection and response to nuclear terrorism. In 2007, India became a part of GICNT India adheres to the GICNT mandate, but recurrent nuclear theft incidents show that the country faces significant challenges regarding physical protection and regulatory oversight of nuclear material.[15]

Furthermore, the Convention on, "the Physical Protection of Nuclear Material" demands from states to take definite measures. According to this convention states must "make specific arrangements and meet defined standards of physical protection for international shipments of nuclear material for peaceful purposes (plutonium, uranium 235, uranium 233 and irradiated fuel), according to Annexes I and II and IAEA INFCIRC/225".[16] It also states, a state "undertake not to export or import nuclear materials or to allow their transit through their territory unless they have received assurances that these materials will be protected during international transport in accordance with the levels of protection determined by the Convention." In addition, following are the important points of this convention:

- "co-operate in the recovery and protection of stolen nuclear material, by sharing information on missing nuclear materials.

[15] Rahat Iqbal, Murad Ali "Lapses in Indian Nuclear Security Mechanism and Its Broader Implications," *PolicyEast*, accessed July 25, 2024, https://policyeast.com/lapses-in-indian-nuclear-security/.
[16] Bettauer.

- criminalize specified acts, including misusing or threatening to misuse nuclear materials to harm the public; and
- prosecute or extradite those accused of committing such acts. States Parties undertake to include those offenses as extraditable offenses in every future extradition treaty to be concluded between them."[17]

Indian Nuclear Security Architecture

The security protocols that India follows for nuclear security include:[18]

1) deter unauthorized access to the source or source location, in order to deter theft;
2) detect any such attempts at unauthorized access;
3) delay unauthorized access or theft;
4) provide rapid response to attempts at unauthorized access or theft; and ensure the reliability of personnel involved in managing sources.

Indian nuclear security architecture consists of four major elements. These include international cooperation, national governance framework, institutions, technology and nuclear security practice and culture. India is a signatory to the Convention on the Physical Protection of Nuclear Material (CPPNM) and its amendment in 2005 for the protection of nuclear material and facilities from thefts and sabotage. Nevertheless, the implementation of this convention at national regulatory framework faces certain challenges as is evident from nuclear thefts in India.[19] Also, the international regulatory oversight is lacking for Indian unsafeguarded civil nuclear facilities, thereby, increasing the probability of more nuclear theft incidents in the future.

2. Governance Framework and Institutions

Regarding Indian governance framework, the Prime Minister of India is the ultimate authority and has responsibility for the oversight of atomic energy and relevant policies. Nuclear polices and their respective guidance and direction is the mandate of Atomic Energy Commission (AEC). The responsibility of implementation and programs regarding atomic energy is the Department of Atomic Energy (DAE). The Atomic Energy Regulatory Board (AERB) is the major agency which deals with safety and security compliance regarding nuclear facilities, however it is dependent on

[17] Bettauer.
[18] Government of India, AERB "Security of Radioactive Sources in Radiation Facilities," March 2011.
[19] "Evaluating Nuclear Trafficking Threat in India," *Asiafreepress* (blog), September 20, 2021, https://www.asiafreepress.com/en/review/perspective/evaluating-nuclear-trafficking-threat-in-india/.

and controlled by AEC. Analysts also argue that AERB has no jurisdiction in deciding, increasing or imposition of fines and penalties or altering nuclear regulations to counter nuclear security offenses.[20]

The Bhabha Atomic Research Centre (BARC) is responsible for nuclear related research. Furthermore, Nuclear Power Corporation of India Limited (NPCIL) is responsible for smooth operation of the Nuclear Power Plants (NPPs). Indira Gandhi Centre for Atomic Research (IGCAR) is responsible for research in the field of nuclear sciences. Uranium mining as well as fuel manufacturing comes under Uranium Corporation of India Limited (UCIL). The Electronics Corporation of India Limited (ECIL) is responsible for development and supply of electronics for nuclear facilities. Radiation and Isotope technologies and their research and applications come under the Board of Radiation and Isotope Technology (BRIT). Lastly, international collaboration regarding nuclear security is overseen by the Global Centre for Nuclear Energy Partnership (GCNEP). Following is the hierarchical structure of India's atomic energy establishment .

[20] Union Government Department of Atomic Energy "Report of the Comptroller and Auditor General of India on Activities of Atomic Energy Regulatory Board," n.d.

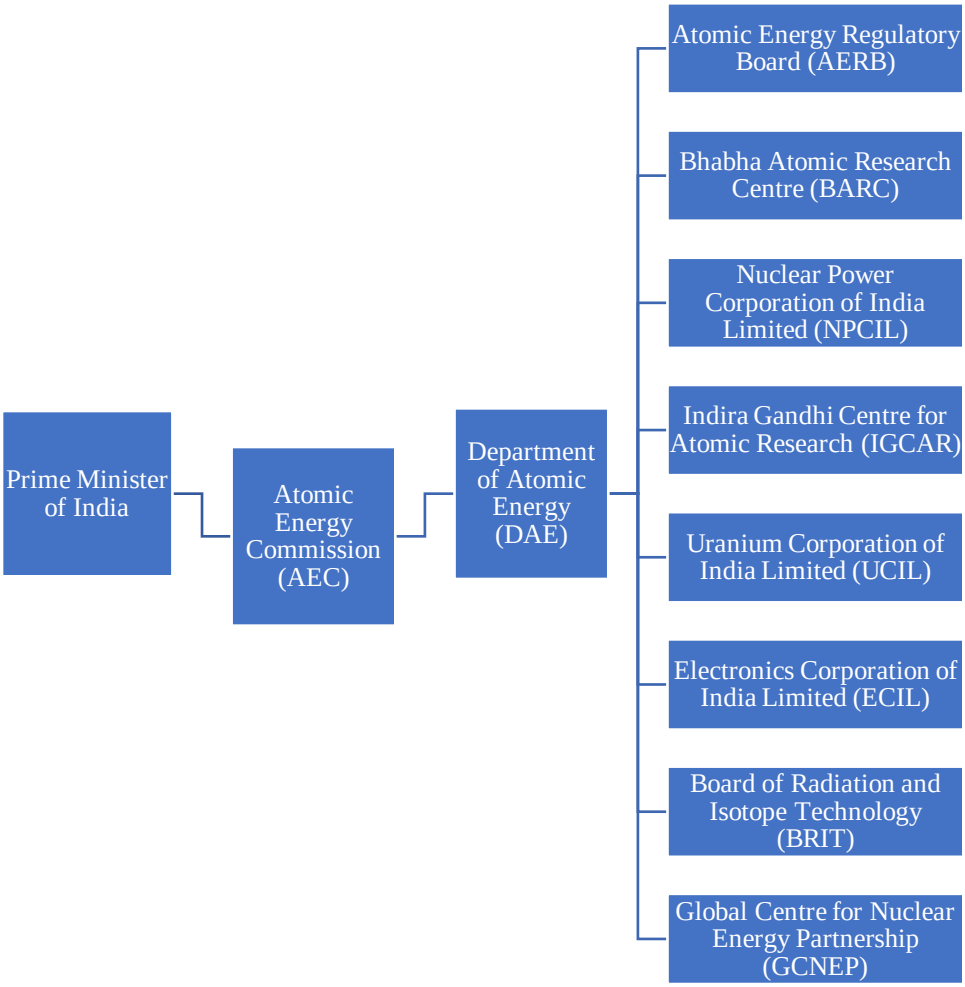

Figure I: Hierarchical Structure of India's Atomic Energy Establishment

Laws that deal with legal issues vis-à-vis nuclear security in India include:

a) Atomic Energy Act 1962
b) Rules on Safe Disposal of Radioactive Waste 1987
c) Radiation Protection Act 2004
d) The Foreign Trade Development Act 1992
e) Weapons of Mass Destruction Act 2005

India has a specially trained para-military force 'Central Industrial Security Force' which is deployed at the nuclear facilities for their security which works under the Ministry of Home Affairs.

3. Indian Nuclear Security Culture

Nuclear security is a national responsibility, and nuclear security culture plays a vital role in enhancing nuclear security of a country. India's nuclear security culture is evolving. Nevertheless, the recent incidents show that the application Indian nuclear security culture has either become redundant or are not changed according to the requirements of the global nuclear security environment. If India possesses world's best nuclear technology and infrastructure, it will face security risks if nuclear security culture is not practiced. For instance, the implementation of norms and rules for stringent nuclear security mechanisms must be adopted to ensure nuclear security and safety. For instance, according to Jayarajan Kutuvan Bhabha Atomic Research Centre, nuclear security culture often evolves slowly as it resists change.[21] This is often reflected in the saying that "good security is 20% equipment and 80% people."[22]

To teach nuclear security programs to security personnel, individuals in the nuclear field as well as agencies, under the GCNEP, India has only one school on nuclear security. The Homi Bhabha National Institute (HBNI) offers a one-year training program under which nuclear security is one section of the course. Furthermore, nuclear facilities and regulators also conduct workshops and seminars on nuclear security. Since 1991 India has been unable to halt uranium thefts, place all its civil nuclear facilities under IAEA safeguards, and protect its nuclear facilities from cyber-attacks.

A. Incidents of Uranium Thefts in India

There are grave risks if such material gets into wrong hands. For instance, the stolen nuclear material could be used to make a dirty bomb, thereby, the increase in such incidents of theft of nuclear material could result in nuclear terrorism. Nuclear terrorism can be defined as, "acts of violence and destruction performed by non-state actors where the means applied are nuclear explosive devices – or threats of such actions – with the purpose of inflicting destruction, creating

[21] Jayarajan Kutuvan, "Building Robust Nuclear Security Culture in Nuclear Research Centers" (IAEA, n.d.).
[22] National Academy of Sciences; National Institute for Advanced Studies, Bangalore, India; Committee on International Security and Arms Control; Committee on India-United States Cooperation on Global Security: Technical Aspects of Civilian Nuclear Materials Security; Rita Guenther, Micah Lowenthal, Rajaram Nagappa, and Nabeel Mancheri, Rapporteurs, "India-United States Cooperation on Global Security: Summary of a Workshop on Technical Aspects of Civilian Nuclear Materials Security | The National Academies Press," accessed July 29, 2024, https://nap.nationalacademies.org/catalog/18412/india-united-states-cooperation-on-global-security-summary-of-a?utm_expid=4418042-5.krRTDpXJQISoXLpdo1Ynw.0&utm_referrer=http%3A%2F%2Fisssp.in%2Findia-united-statescooperation-on-global-security%2F.

a condition of fear, getting attention, blackmailing, installing instability, and to affect an audience beyond the victim directly targeted."[23]

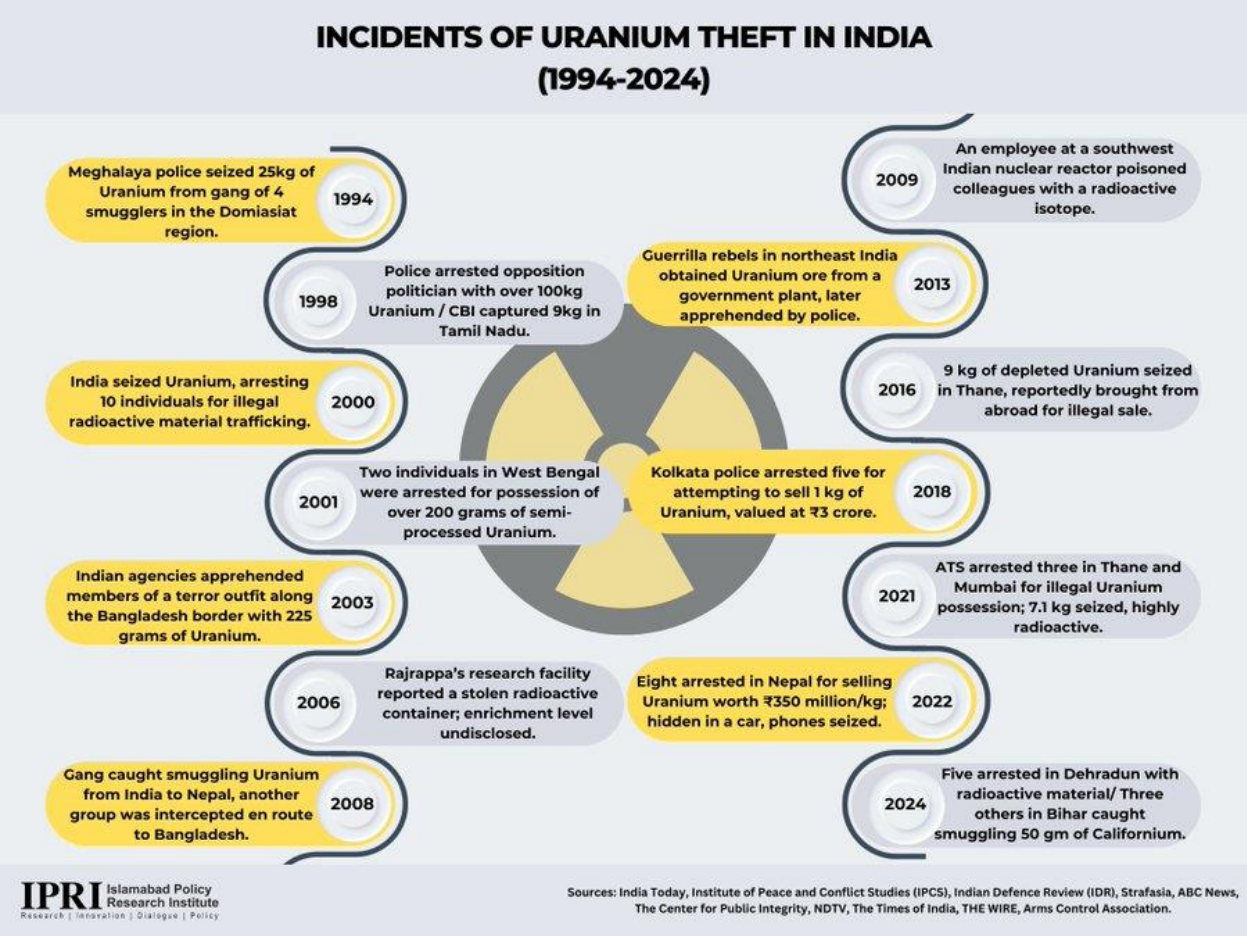

Figure II: Incidents of Uranium Theft in India[24]

The above infographic shows that there have been three kinds of uranium theft incidents. Firstly, uranium was stolen by insiders working at the nuclear facilities like the incident in 2009. Secondly, individuals were caught who wanted to proliferate such material outside the country as an illegal export or import – indicating possible links to nuclear black market. Thirdly, there were incidents which involved non-state actors seizing nuclear material. There can be many repercussions because of inadequate nuclear security of facilities and material.

[23] http://www.idsa.in/system/files/Monograph27.pdf
[24] Islamabad Policy Research Institute [@IPRI_Pak], "IPRI Infographics| Incidents of Uranium Theft in India Here's an Infographic Mapping Uranium Thefts in India in the Past 30 Years #India #Uranium #Nuclear #NuclearPower #NuclearTheft @iaeaorg @UN @NTI_WMD Https://T.Co/IcN9HV305i," Tweet, *Twitter*, July 25, 2024, https://x.com/IPRI_Pak/status/1829866732309389380.

B. Indian Safeguarded and Unsafeguarded Civilian Nuclear Facilities

Indian civil nuclear facilities consist of fast breeder reactors and pressurized heavy water reactors (PHWRs). India is also increasingly interested in thorium-based breeders because of its indigenous thorium reserves.[25] In March 2024, India commenced the fuel loading of its MWE 500 fast breeder reactor.[26] As much as Indian nuclear program is expanding, the need for stringent nuclear security measures has also become increasingly evident.

As part of 2008 Indo-US Civil Nuclear Agreement, India has put some of its civilian nuclear facilities under IAEA Safeguards. According to IAEA's Information Circular No INFCIRC/754/Add.12, there are 31 civilian nuclear facilities under IAEA Safeguards. Furthermore, some civilian unsafeguarded nuclear facilities are not under IAEA Safeguards particularly because of either their importance for strategic purposes or domestic fuel cycle being used in those facilities. For instance, Kudankulam Atomic Power Station (Units 1 & 2) are under IAEA safeguards as they are of Russian origin, further Units 3 and 4 remain unsafeguarded. Similarly, Madras Atomic Power Station (MAPS) and its Units 1 and 2 are not under IAEA safeguards despite these being civilian nuclear facilities. Also, the Kalpakkam Prototype Fast Breeder Reactor (Kalpakkam) remains outside IAEA safeguards because of its plutonium generation is reported to be used for Indian nuclear weapons program. The following are the 31 civilian nuclear facilities under IAEA safeguards: [27]

[25] M V RaMaNa, "The Indian Nuclear Industry: Status and Prospects," *The Centre for International Governance Innovation* 1 (2009).
[26] Department Of Atomic Energy India, "Witnesses the Historic 'Commencement of Core Loading' at India's First Indigenous Fast Breeder Reactor (500 MWe) at Kalpakkam, Tamil Nadu," accessed July 25, 2024.
[27] IAEA Database "Infcirc754a12," accessed July 25, 2024, https://www.iaea.org/sites/default/files/publications/documents/infcircs/2009/infcirc754a12.pdf.

Ser No	Facility Name
1	Uranium Oxide Plant, Nuclear Fuel Complex, Hyderabad
2	Ceramic Fuel Fabrication Plant (Pelletizing), Nuclear Fuel Complex, Hyderabad
3	Ceramic Fuel Fabrication Plant (Assembly), Nuclear Fuel Complex, Hyderabad
4	Enriched Uranium Oxide Plant, Nuclear Fuel Complex, Hyderabad
5	Enriched Fuel Fabrication Plant, Nuclear Fuel Complex, Hyderabad
6	Gadolinia Facility, Nuclear Fuel Complex, Hyderabad
7	TAPS 1 – Tarapur Atomic Power Station, Unit 1
8	TAPS 2 – Tarapur Atomic Power Station, Unit 2
9	RAPS 1 – Rajasthan Atomic Power Station, Unit 1
10	RAPS 2 – Rajasthan Atomic Power Station, Unit 2
11	KK 1 – Kudankulam NPP, Unit 1
12	KK 2 – Kudankulam NPP, Unit 2
13	RAPS 5 – Rajasthan Atomic Power Station, Unit 5
14	RAPS 6 – Rajasthan Atomic Power Station, Unit 6
15	RAPS 3 – Rajasthan Atomic Power Station, Unit 3
16	RAPS 4 – Rajasthan Atomic Power Station, Unit 4
17	KAPS 1 – Kakrapar Atomic Power Station, Unit 1
18	KAPS 2 – Kakrapar Atomic Power Station, Unit 2
19	Away from Reactor (AFR) Fuel Storage Facility, Tarapur
20	Nuclear Material Store at Tarapur
21	NAPS 1 – Narora Atomic Power Station, Unit 1
22	NAPS 2 – Narora Atomic Power Station, Unit 2
23	KAPS 3 – Kakrapar Atomic Power Station, Unit 3
24	KAPS 4 – Kakrapar Atomic Power Station, Unit 4
25	KK 3 – Kudankulam NPP, Unit 3
26	KK 4 – Kudankulam NPP, Unit 4
27	RAPS 7 – Rajasthan Atomic Power Station, Unit 7
28	RAPS 8 – Rajasthan Atomic Power Station, Unit 8
29	PHWR Fuel Fabrication Facility (PFFF) NFC – Kota, Rajasthan
30	KK 5 – Kudankulam NPP, Unit 5
31	KK 6 – Kudankulam NPP, Unit 6

Following are the unsafeguarded civilian facilities that are not under IAEA Safeguards.[28]

Ser No	Facility Name	Safeguards Status	Type	Location	Description
1	Dhruva Reactor[29]	Unsafeguarded	Research Reactor	Trombay, Maharashtra	Used for plutonium production and civil research, not under IAEA safeguards.[30]
2	Madras Atomic Power Station (MAPS)	Unsafeguarded	Pressurized Heavy Water Reactor	Kalpakkam, Tamil Nadu	Civil nuclear power reactor units 1 and 2 are not under IAEA safeguards.
3	Kaiga Atomic Power Station (KAPS)	Unsafeguarded	Pressurized Heavy Water Reactor	Kaiga, Karnataka	Civil nuclear power reactors, units 1-4, remain unsafeguarded.
4	Fast Breeder Test Reactor (FBTR)	Unsafeguarded	Fast Breeder Reactor	Kalpakkam, Tamil Nadu	Experimental fast breeder reactor, outside IAEA safeguards.
5	Prototype Fast Breeder Reactor (PFBR)	Unsafeguarded	Fast Breeder Reactor	Kalpakkam, Tamil Nadu	Under construction, designed for plutonium breeding, not under IAEA safeguards.

[28] Data collected from different sources by the author.
[29] "Nuclear Power in India - World Nuclear Association," accessed July 25, 2024, https://world-nuclear.org/information-library/country-profiles/countries-g-n/india#research-amp-development.
[30] "India - International Panel on Fissile Materials," IPFM, accessed July 25, 2024, https://fissilematerials.org/countries/india.html.

6	Tarapur Atomic Power Station (TAPS) 3 & 4	Unsafeguarded	Boiling Water Reactor	Tarapur, Maharashtra	Units 3 & 4 of Tarapur are not under IAEA safeguards.

C. Cyber Attacks on Indian Nuclear Facilities

In the rapidly changing world, there is an increased risk of cyber-attacks on nuclear facilities that could be used in conjunction with sabotage as well as theft of nuclear material from a facility. Indian nuclear facilities have been targets of cyber-attacks in the past as well. For instance, in 2019, Indian Kudankulam NPP was attacked by a 'D-Track' malware carried out by North Korean hackers.[31] Around the same timeline, the NPCIL's network was breached that highlights the vulnerabilities of Indian nuclear infrastructure.[32]

In order to carry out a cyber-attack, the hackers require only partial control of inner network. This means that the targeted Indian NPPs have a number of security issues, such as rudimentary cyber hygiene policy, weak network security policies, weak password policies and lack of traffic monitoring. Such cyber-attacks in India have renewed potential for insider threat in Indian NPPs.[33] The reason provided for the denial of the attack due to stand alone network portrays flaws in the Indian cyber security where physical separation from global network or "air-gapping" is deemed enough as a protective measure.

D. Issues Regarding International Cooperation

In the past, the issues related to domestic legal frameworks have raised concerns among states conducting nuclear trade vis-à-vis nuclear deals with India.[34] For instance, the Civil Liability for Nuclear Damage Act 2010 was a major hurdle where the liability of nuclear accidents was placed

[31] "What Is DTrack: North Korean Virus Being Used to Hack ATMs to Nuclear Power Plant in India," *India Today*, October 30, 2019.
[32] Debak Das et al., "Analysis | An Indian Nuclear Power Plant Suffered a Cyberattack. Here's What You Need to Know.," *Washington Post*, November 4, 2019.
[33] "What Is Cyber Hygiene and Why Is It Important?" Search Security, accessed July 25, 2024, https://www.techtarget.com/searchsecurity/definition/cyber-hygiene.
[34] "Completing the U.S.-India Civil Nuclear Agreement: Fulfilling the Promises of a Summer Long Past," Carnegie Endowment for International Peace, accessed July 25, 2024.

on the foreign nuclear suppliers including the Indo-US civil nuclear deal in 2008.[35] International companies like Électricité de France and Japanese company Toshiba (Owner of Westinghouse) have showed concerns for Indian domestic nuclear liability regime.[36] Furthermore, International nuclear suppliers have raised concerns regarding public protests against NPPs built in India. These include protests in Kudankulam, Huripur and Kovvada among others regarding nuclear safety and security issues and fears of displacement.

Assessment and Recommendations

1. Domestic Regulatory Gaps

Because of secrecy revolving around Indian nuclear security, it is difficult to give an independent assessment of nuclear security in India.[37] Nevertheless, the recurrent uranium thefts in India show that apart from the fourth tier of rapid response to theft, India lags in deterring, detecting and delaying unauthorized access or theft. For instance, the domestic theft and trafficking of nuclear material indicates the lack of coordination among the stakeholders involved in nuclear security forces. These include law enforcement agencies, intelligence agencies and security force under nuclear regulatory authorities.

India needs to make the AERB independent and autonomous in order to standardize nuclear security architecture. It will help AERB to regulate nuclear issues rather than a subordinate office which is delegated functions and roles by the Central Government.[38] Moreover, the analysis of Indian nuclear security reflects that there is an absence of a centralized governing nuclear security apparatus of law enforcement in India and also within the Central Industrial Security. For instance, the security force includes members from many organizations which may not necessarily give the same importance to nuclear security.[39]

[35] "Operationalizing India-U.S. Civil Nuclear Cooperation," *Brookings,* accessed July 25, 2024, https://www.brookings.edu/articles/operationalizing-india-u-s-civil-nuclear-cooperation/.
[36] "Jaitapur Nuclear Power Plant for India: What You Should Know - ExamArc," April 26, 2023, https://guide.examarc.com/upsc/jaitapur-nuclear-power-plant-for-india-what-you-should-know/.
[37] Gurmeet Kanwal, "Safety and Security of India's N-Weapons," IDSA, accessed July 27, 2024, https://ciaotest.cc.columbia.edu/olj/sa/sa_apr01kag01.html.
[38] "Why India's Nuclear Security Challenge Demands Attention," orfonline.org, accessed July 27, 2024, https://www.orfonline.org/english/research/42286-why-india-nuclear-security-challenge-demands-attention.
[39] "Why India's Nuclear Security Challenge Demands Attention."

2. Insider Threats

The involvement and links of scientists and workers at nuclear facilities in nuclear thefts indicates that training regarding nuclear security including rules and regulations to ensure the reliability of personnel involved at nuclear facilities are below average.[40] India needs to continuously evolve and modernize its nuclear security culture according to changing nuclear risks. There is a need for recurrent training programs for employees from all levels.[41] India needs to assess gaps in its nuclear security framework, particularly in protocols preventing unauthorized access to nuclear material.[42]There is also a need to counter such vulnerabilities by enhancing its control and accounting of nuclear material.

3. Physical Protection, Storage and Transportation

Indian nuclear theft incidents also indicate gaps between physical protection, storage and transportation. Due to expansion of Indian nuclear facilities across Indian remote areas, it is challenging for India to monitor or secure them. These remote areas also have instabilities like insurgencies and militant groups.[43] For Instance, the Kaiga Atomic Power Station located in Karnataka is an unsafeguarded nuclear facility which is in proximity to the Naxalite-Maoist insurgency.[44] Such close proximity of insurgent groups to these critical nuclear facilities increases their security vulnerabilities, thereby, turning such facilities more prone to sabotage and theft of nuclear material into anti-state militant groups.[45]

4. Indian Nuclear Black Market

In 2011, research into potential Indian black market indicated that India had been a customer of international black market.[46] In 2007, the IISS Dossier[47] on nuclear black market also indicated

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[40] "Lapses in Indian Nuclear Security Mechanism and Its Broader Implications - PolicyEast."
[41] Rahat Iqbal, "Evaluating Nuclear Security in India," *Centre for Strategic and Contemporary Research* (blog), October 5, 2022.
[42] Muhammad Zubair et al., "Nuclear Safeguards: Technology, Challenges, and Future Perspectives," *Alexandria Engineering Journal* 108: 188–205, https://doi.org/10.1016/j.aej.2024.07.055.
[43] Michael Kugelman, "The 'Gravest Threat' to Internal Security: India's Maoist Insurgency," Wilson Center, accessed July 30, 2024.
[44] Muhammad Jawad Hashmi and Dr. Ashfaq Ahmed, "Threats of Nuclear Terrorism in India: A Case Study of Naxalites," *Journal of Global Peace and Security Studies* 3, no. 1 (2022).
[45] Muhammad Jawad Hashmi and Dr. Ashfaq Ahmed.
[46] Matthew Bunn and William C. Potter, "Introduction: The Problem of Black-Market Nuclear Technology Networks," in *Preventing Black-Market Trade in Nuclear Technology*, ed. Matthew Bunn et al., 1st ed. (Cambridge University Press, 2018), 1–22.
[47] "Nuclear Black Markets: Pakistan, A.Q. Khan and the Rise of Proliferation Networks (A Net Assessment) (An IISS Strategic Dossier) - The International Institute for Strategic Studies: 9780860792017 - AbeBooks," accessed July 27, 2024, https://www.abebooks.com/9780860792017/Nuclear-Black-Markets-Pakistan-A.Q-0860792013/plp.

that India's BARC, DAE and NPCIL and Indian Rare Earths Ltd (IRE) have been involved in procurement and/or facilitation of nuclear material such recurrent incidents indicate linkages of insiders as well as non-state actors with the global black market are still a challenge to global nuclear non-proliferation efforts. Access to such nuclear material can have broader implications where non-state actors can use these materials for malicious activities.

5. Access to Non-State Actors and making of a Dirty Bomb

A smaller nuclear weapon may require at least 15 kgs of Highly Enriched Uranium (HEU). [48]Terrorists and non-state actors may not have the knowhow, expertise and facilities to build a nuclear bomb. [49]Alternatively, such individuals with malicious intent including non-state actors could use a radioactive material for making Radiological Dispersal Device (RDD) or dirty bombs.[50] The RDDs do not necessarily require technical expertise or certain types of nuclear material. Moreover, the non-state actors could sell such material to other states which may wish to acquire such material for military purposes. Hence, it is important for India to take all the necessary measures to secure its nuclear material and facilities.[51]

6. Enhancing Cyber Security

Regarding cyber security of nuclear material and facilities in India, concerned organizations need to have a relook on complete cycle of cyber security of NPPs.[52] This can start from vendor/software selection and going down to minor issues like access control and data copyrights etc. Moreover, there is a need to augment and review Indian cyber security culture regarding nuclear facilities and material through enhancing and updating cybersecurity protocols. [53]There is also a need for implementation of robust encryption and intrusion detection systems in nuclear facilities. India can enhance protocols to follow the record of cybersecurity breaches by involving international players while investing in regular cybersecurity audits and training.[54]

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[48] B. L. Metcalfe and I. W. Donald, "25 - Management of Radioactive Waste (RAW) from Nuclear Weapons Programmes," in *Radioactive Waste Management and Contaminated Site Clean-Up*, ed. William E. Lee, Michael I. Ojovan, and Carol M. Jantzen, Woodhead Publishing Series in Energy (Woodhead Publishing, 2013), 775–800.
[49] Christoph Wirz and Emmanuel Egger, "Use of Nuclear and Radiological Weapons by Terrorists?" *International Review of the Red Cross* 87, no. 859 (September 2005): 497–510.
[50] Wirz and Egger.
[51] Wirz and Egger.
[52] "Ensuring Cyber Security in India's Nuclear Systems," orfonline.org, accessed July 27, 2024, https://www.orfonline.org/research/ensuring-cyber-security-in-indias-nuclear-systems.
[53] "Ensuring Cyber Security in India's Nuclear Systems."
[54] Ibid.

If India does not cater for or prevent such nuclear security incidents from happening by taking necessary measures, the international community may devise a strategy to put brackets on nuclear cooperation with India until India places stringent implementation measures regarding nuclear security of its nuclear material and facilities. There is a dire need for increased oversight into all of Indian civilian nuclear facilities. India may consider offering all of its current and future nuclear facilities under IAEA safeguards.[55]

Moreover, the states which have signed nuclear deals with India could halt their nuclear cooperation and demand investigation into past incidents and enforce nuclear security implementation mechanism in India as a quid pro quo to restart nuclear cooperation. One of the reasons India was not able to secure its membership in Nuclear Suppliers Group (NSG) is also its inadequate nuclear security infrastructure. [56] Hence, Indian uranium security lapses call into question India's credentials as well as readiness for further integration into the global nuclear governance through export control cartels including the NSG until it improves its nuclear security architecture and implementation.[57]

Lack of International Pressure

The geopolitical environment of the 21st century offers India a unique and favorable position, particularly in the context of the evolving dynamics between major global powers. [58] With the United States engaged in strategic competition with China, India's role as a potential counterbalance in the Indo-Pacific region has gained unprecedented prominence.[59] This strategic alignment has created a confluence of interests between India and the United States, albeit with limitations and divergences in specific areas. [60] Nevertheless, this alignment has indirectly shielded India from international scrutiny on sensitive issues, including concerns such as uranium theft and its potential implications for nuclear security. [61] The United States' Indo-Pacific strategy is

[55] "Lapses in Indian Nuclear Security Mechanism and Its Broader Implications - PolicyEast."
[56] "Will India and Pakistan Ever Join the Nuclear Suppliers Group? | Arms Control Association," accessed July 27, 2024.
[57] "Will India and Pakistan Ever Join the Nuclear Suppliers Group? | Arms Control Association."
[58] Vinay Kaura, "India's Emerging Geopolitics," in *The Palgrave Handbook of Contemporary Geopolitics*, ed. Zak Cope (Cham: Springer Nature Switzerland, 2024), 1–19.
[59] Kaura.
[60] Marko Juutinen, "Emerging Powers and New Global Politics? An Indian Perspective on the BRICS Paradox," *Third World Thematics: A TWQ Journal* 4, no. 6 (November 2, 2019): 489–506.
[61] Juutinen.

centered on curbing China's growing influence in the region. [62] India, with its significant geographic and strategic advantages, plays a pivotal role in this framework.[63]

As a member of the Quad (Quadrilateral Security Dialogue) alongside the US, Japan, and Australia, India is viewed as a key player in ensuring a "free and open Indo-Pacific."[64] This strategic partnership has resulted in deepening defense cooperation, enhanced military interoperability, and increased political alignment on key regional security issues.[65]Due to this reason, India's domestic policies, including those related to human rights and press freedom, have drawn muted criticism from Washington but have not significantly impacted the trajectory of bilateral relations.[66] This limited alignment and the overriding strategic imperative to counter China have also contributed to an international environment where issues like uranium theft in India do not receive significant attention. Incidents of uranium theft, which pose serious risks to nuclear security, have been reported in India over the years. [67]However, these cases have largely been downplayed in international forums, reflecting a reluctance among major powers and international institutions to antagonize India. The prevailing view appears to prioritize maintaining strategic partnerships over addressing such critical security concerns.[68]

International institutions tasked with overseeing nuclear security, such as IAEA, have been conspicuously silent on India's uranium theft incidents. This silence can be attributed to the geopolitical calculus of major powers that dominate these institutions. [69]The US, with its significant influence in international bodies, is unlikely to push for stringent scrutiny of India, given its strategic importance in the Indo-Pacific theater.[70] Moreover, India's growing economic clout and its position as a rising power provide it with leverage in international diplomacy.

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[62] C. Vinodan and Anju Lis Kurian, "Strategic Autonomy and India's Hedging Policies in the Indo-Pacific," *Journal of Asian Security and International Affairs* 11, no. 4 (2024): 475–95, https://doi.org/10.1177/23477970241282095.
[63] Vinodan and Kurian.
[64] Kate Sullivan de Estrada, "India and Order Transition in the Indo-Pacific: Resisting the Quad as a 'Security Community,'" *The Pacific Review* 36, no. 2 (March 4, 2023): 378–405, https://doi.org/10.1080/09512748.2022.2160792.
[65] Sullivan de Estrada.
[66] Mehmood Hussain and Sumara Mehmood, "Genocide in Kashmir and the United Nations Failure to Invoke Responsibility to Protect (R2P): Causes and Consequences," *Muslim World Journal of Human Rights* 18, no. 1 (September 1, 2021): 55–77.
[67] Ghazala Yasmin Jalil, "Issue Brief on 'India Nuclear Black Market' | Institute of Strategic Studies Islamabad," 2024, https://issi.org.pk/issue-brief-on-india-nuclear-black-market/.
[68] Jalil.
[69] Ibid.
[70] Manish Dabhade, "Changing Contours of India's Economic Diplomacy," *India Quarterly* 78, no. 2 (June 1, 2022): 334–49, https://doi.org/10.1177/09749284221091865.

Countries and institutions are wary of jeopardizing their relations with India by raising uncomfortable questions, even on matters as critical as nuclear material security.[71]

The geopolitical environment has provided India with a shield against significant international criticism, even on issues of global concern like uranium theft.[72] The strategic priorities of the US and the broader international community, centered on countering China and fostering closer ties with India, have created a permissive environment.[73] While this may serve short-term strategic interests, it raises long-term concerns about the potential risks to nuclear security and the credibility of international institutions tasked with ensuring accountability.[74]

Conclusion

Nuclear technology provides tremendous benefits, as it can become catastrophic beyond one state's territory if it gets into wrong hands. While India has taken measures to strengthen its nuclear security architecture both nationally and internationally, significant gaps remain in regulatory framework and implementation and enforcement measures. Moreover, the lack of an independent regulatory body – which has limited resources – coupled with inadequate coordination for nuclear security forces among agencies will continue to pose significant challenges to India's overall nuclear security. Hence, thefts of at least 200 kgs uranium, cyber-attacks on nuclear facilities for sabotage and unsafeguarded civilian nuclear facilities prone to nuclear security incidents highlights gaps in nuclear security architecture in India. These incidents do not only impact Indian national nuclear security architecture, but also have broader implications on nuclear non-proliferation efforts. Thus, there is a need for states like India to not be complacent regarding nuclear security practices and mitigate such risks. If India fails to do so, the international community will need to put brackets on Indian civil nuclear program and international cooperation until India further enhances its nuclear security through making its regulatory body independent, enhancing nuclear security culture, implementation of nuclear regulations and improving coordination between law enforcement and intelligence gathering agencies. This will help restore international confidence in Indian capabilities to proactively manage its nuclear security responsibilities.

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[71] Dabhade.
[72] "India's Uranium Theft Crisis and the International Silence," *The Friday Times*, 2024, https://thefridaytimes.com/26-Sep-2024/the-persistent-crisis-of-uranium-theft-in-india-and-the-international-silence.
[73] "India's Uranium Theft Crisis and the International Silence."
[74] Ibid.