Planning for the Worst

Nuclear Effects & Disaster Management in South Asia

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Executive Summary

The Stimson Center, in collaboration with the Regional Centre for Strategic Studies, hosted a workshop on nuclear effects in South Asia in Colombo, Sri Lanka from February 23-25, 2018. The workshop facilitated discussions in which participants worked through the effects of low-probability, high-risk nuclear events that might occur in the region. The four specific "unthinkable" or "black swan" scenarios considered in the exercise varied in intentionality and kinetics: a radiological dispersal device terror attack, a nuclear plant accident, a nuclear weapons accident, and a limited nuclear exchange. Short-, medium-, and long-term effects considered included general *types*—strategic, political, social/economic, and environmental/public health. Analysts and scholars from India, Pakistan, Sri Lanka, and the United States participated in research paper presentations, panel discussions, and small- and large-group breakout sessions. This report includes the full scenarios used by participants and summarizes workshop findings.

Key conclusions drawn from the workshop include:

- **Nuclear effects are underappreciated.** Compared to the safety and security challenges prior to a nuclear event, states, their publics, and the international community are less aware of the magnitude of consequences or prepared for the challenges of coordinated management required *after* a major nuclear event. There is both a need for and apparent interest in new research on the effects of nuclear events and resilience planning.

- **Nuclear events are strategic.** Security concerns are inherent in all things nuclear, and military involvement will be inevitable. At the same time, military involvement can impact military readiness and deterrence, rendering all nuclear scenarios—whether accidental or intentional—strategic concerns.

- **Information challenges abound.** In the aftermath of a nuclear event, states will face tradeoffs—between strategic, political, social/economic, and environmental/public health objectives—in deciding when and how to share information with domestic, regional, and international stakeholders.

- **Consequence management ripe for cooperation and discussion.** Focusing on the after-effects of black swan nuclear events that could mutually affect adversarial parties—together with third parties—may foster less contentious and more productive discussion on normally sensitive security topics. This may stem from a mutual need for information and contingency plans amidst the paucity of research, empirical data, or advanced scenario analysis on nuclear effects.

Introduction

Overview

The risk of nuclear disasters constitutes a national and transnational threat. The effects of nuclear events—from radioactive pollution in the atmosphere sourced to nuclear facilities leakage[1] to a detonation of a nuclear weapon—inherently cross borders and carry global implications. Preparing for the management of disastrous nuclear events—intentional, inadvertent, or accidental—along with their second- and third-order effects requires continuous scrutiny, regardless of a state's experience with nuclear weapons and nuclear reactors.[2]

The objective of this workshop was to engender analysis on the various effects of and preparedness for low probability/high consequence nuclear events in South Asia. Participants included analysts, scholars, and consequence management practitioners, with functional and/or regional expertise from South Asia and the United States. The workshop elicited fresh perspectives on the consequences of nuclear disasters including their potential range, extent, and implications, the demands such effects will place on governments, and planning mechanisms that policymakers might consider.

Design

Based on a 10-page concept paper detailing the scenarios circulated in advance of the workshop, participants were asked to contemplate four general *types* of effects—strategic, political, social/economic, and environmental/public health—over the short- (1-2 weeks), medium- (6-12 months), and long-terms (5-10 years).

The workshop employed a number of formats to elicit creative thinking, including: preparatory research/writing of a scenario exercise paper; expert presentations; academic conference-style panels; and small, breakout group discussions. Scenarios were designed as limited and narrow in scope in order to reduce barriers to plausibility and focus participants on contemplating effects rather than "fighting the scenario." Large- and small-group discussions allowed for sensitivity analysis by "stretching" the scenario to vary the parameters and severity. For a multi-disciplinary approach, participants included scholars from fields including strategic studies, international relations, economics, physics, medicine, public health, and urban politics. The diverse group featured fourteen women and sixteen men—ten scholars from India, ten from Pakistan, three from Sri Lanka, and seven from the United States (including Stimson Center facilitators).

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[1] Alan Cowell, "A Radioactive Cloud Wafts Over Europe, With Russia as Chief Suspect," *New York Times*, November 15, 2017.

[2] In 2014, the US National Academies of Sciences organized a symposium on "The Science and Response to a Nuclear Reactor Accident," https://www.ncbi.nlm.nih.gov/books/NBK268796/; There are similar efforts in other states and by bodies such as the International Red Cross through its chemical, biological, radiological or nuclear (CBRN) Operational Response Project. Dominique Loye and Robin Coupland, "Who Will Assist the Victims of Use of Nuclear, Radiological, Biological or Chemical weapons – and How?" *International Review of the Red Cross* 89, no. 866 (2007), available at www.icrc.org/eng/assets/files/other/irrc_866_loye.pdf.

Objectives

The purpose of this workshop was not to conduct a risk assessment exercise of nuclear safety or security on the subcontinent. Nor was it to identify or evaluate mechanisms for escalation control or confidence building between nuclear-armed states. Rather, Stimson aimed to facilitate a collaborative discussion of the effects over varying time horizons if the unthinkable were to occur, and potential management mechanisms for such a scale of disaster. Practically, the workshop served three functions:

- **Research Workshop**. In order to ensure rich, scholarly discussions, each participant was asked to prepare a footnoted, three-page scenario-analysis research paper wrestling with a particular type of *effect* after a particular *event* (e.g. socio-economic effects of a limited nuclear exchange, or strategic effects of a nuclear plant accident).

- **Simulation Exercise**. During the workshop, several panels, large-group discussions, and breakout sessions pushed participants beyond effects-analysis to contemplate potential and probable state responses to nuclear events, as well as the perspectives and incentives of various actors (principally within the country where the nuclear event took place, but also regional states, major powers, and international institutions).

- **International, Inter-Disciplinary Engagement**. The workshop purposefully balanced scholarly representation from India, Pakistan, and third-party countries (the United States and Sri Lanka) on panels and in breakout discussions. In addition to facilitating richer discussion, a second objective was introducing scholars to each other to foster international and inter-disciplinary academic engagement, and network-building that would endure beyond the workshop itself.

Scenarios & Panel Discussions

Scenario planning provides the means to think about, plan for, and grapple with an unknowable future, free from a fixation on event probabilities. It can enable analysts to confront their assumptions about the past, identify current drivers of change in the strategic environment (and related indicators), and assess plausible futures—as well as the opportunities and threats those futures might contain.[3]

States that have developed nuclear energy programs and/or nuclear weapons programs possess significantly advanced scientific, strategic, military, and political savvy. Nevertheless, history teaches us that accidents, inadvertent mishaps, and undesired interstate conflict can occur. Planning is thus not only prudent but also necessary.

The concept paper circulated in advance to participants detailed the following scenarios.
All scenarios took place in the year 2020. Each provided the type of inexact and incomplete information that policymakers would be faced with in the early aftermath of an event. At the workshop, participants served on panels dedicated to each scenario, presenting short research papers on a specific category of effects.

Panel discussions considered four categories of nuclear effects for each scenario—strategic, political, social/economic, and environmental/public health—in the short-, medium-, and long-term aftermath of a nuclear event. Wrestling with the potential effects of—and preparedness for[4]—a future nuclear disaster begins with considering stakeholders including: the governments and militaries of India and Pakistan, their respective civil societies, regional governments, the United States, China, and other P5 countries, the IAEA, and the United Nations (UN) and UN Security Council.[5] Participants assessed the local, national, regional, and global effects and stakeholder preparedness for the scenarios.

The four event scenarios are outlined below followed by a summary of highlights from each scenario's dedicated panel discussion at the workshop.

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[3] Colin Gray, "Coping with Uncertainty: Dilemmas of Defense Planning," *Comparative Strategy* 27, no. 4 (2008): 324-31; Stephen Fruhling, *Defense Planning and Uncertainty: Preparing for the Next Asia-Pacific War* (New York: Routledge, 2014), 1; and Andrew Krepinevich and Jacob Cohn, "Rethinking Armageddon: Scenario Planning in the Second Nuclear Age," Washington, DC: Center for Strategic and Budgetary Assessments, 2016.

[4] The International Atomic Energy Agency (IAEA) for example, has established and—since the 2011 Fukushima disaster—tested protocols in place for coordinating international response efforts and information exchange during an emergency, together with systems to help member states be prepared for managing nuclear disasters. "IAEA Report on Preparedness and Response for a Nuclear or Radiological Emergency in the Light of the Accident at the Fukushima Daiichi Nuclear Power Plant," https://www.iaea.org/sites/default/files/preparedness0913.pdf. See the section on International Nuclear and Radiological Event Scale (INES) and communicating with the public about radiation exposure in the aftermath of a disaster, 32-34.

[5] The United States, for example, has protocols in place for civilian and military government responses to support management efforts of affected countries in the event of a deliberate or inadvertent chemical, biological, radiological and nuclear incident on foreign territory. The 2011 Fukushima disaster was the first time the U.S. armed forces were involved in such a response effort. Joint Chiefs of Staff, U.S. Department of Defense, Joint Publication 2-41: "Chemical, Biological, Radiological, and Nuclear Response," https://www.hsdl.org/?abstract&did=796157.

Scenario 1: Radiological Dispersion Device Terror Attack

A new era of terrorism is ushered in, as both India and Pakistan become victims of the world's first radiological terror attacks.[6] Analysts have demonstrated that a crude weapon using radiological materials and conventional explosives could be comparatively easy and cheap to make.[7] Terrorist groups like al Qaeda that operate in both India and Pakistan have expressed interest in perpetrating such an attack.[8] In both events described below, the damage in terms of loss of human life and long-term environmental harm is minimal, but the fear introduced by these "weapons of mass disruption" promises to have widespread effects. Experts estimate that the cleanup of contaminated areas will prove expensive.

Agra, India[9]

Three terrorists fight their way into the Taj Mahal during peak tourist season. One assailant makes it through security to detonate an improvised radiological dispersal device (RDD) made with 5 pounds of TNT and 10,000 Curies (9 grams) of Cobalt-60 in the middle of a crowd. 3 tourists (1 domestic, 2 foreign) and 1 security guard are killed by the bomb blast (not radiation). Local Indian authorities are unprepared to speedily initiate decontamination efforts for those exposed to radiation. Medical expert projections for possible future related cancer deaths vary widely, but several media accounts suggest that as many as 50% of the people close to the blast site will be diagnosed with cancer likely as a result of radiation. One of the world's seven wonders is damaged—more in its appeal as a destination than in structural integrity as the blast was quite limited. The small amount of radioactive material emitted is spread northeast, resulting in some contamination of the Yamuna River that will require cleanup. It is unclear who is behind the attack.

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[6] Events resulting in the dispersal of radiological material vary widely in the potential to do harm through radiation itself. Radiation fatalities are less important in these scenarios than other effects. For details on one of the major publicly known radiation accident in South Asia see, Rajoo Kumar (Atomic Energy Regulatory Board, Government of India), "Lessons Learned from the Radiological Accident in Mayapuri, New Delhi, India," Presentation "Safety and Security of Radioactive Sources: Maintaining Continuous Global Control of Sources throughout Their Life Cycle," Abu Dhabi, United Arab Emirates, October 27-31, 2013, available at: https://gnssn.iaea.org/CSN/Abu%20Dhabi%20Conference/Shared%20Documents/Session%207%20presentations/INV-26%20Kumar.pdf; A.B. Dey, S. Mohanan, D. Damodaran, M. Soneja, N. Jain, A. Mohan, NK Vikram, and R. Sood, "Radiation Accident at Mayapuri Scrap Market, Delhi 2010," *Radiat Prot Dosimetry* 151 no. 4 (2012): 645-51.

[7] Patrick Malone, "A Secret Group Easily Bought the Raw Ingredients for a Dirty Bomb—Here in the U.S.," *The Washington Post*, August 4, 2016. For a similar review of how a well-financed, well-organized terrorist group could feasibly create a nuclear (as opposed to radiological) device in a cost-effective manner see, Peter D. Zimmerman and Jeffrey G. Lewis, "The Bomb in the Backyard," *Foreign Policy*, October 16, 2009.

[8] Michael Eisenstadt and Omar Mukhlis, "The Potential for Radiological Terrorism by al-Qaeda and the Islamic State," PolicyWatch 2671, The Washington Institute, http://www.washingtoninstitute.org/policy-analysis/view/the-potential-for-radiological-terrorism-by-al-qaeda-and-the-islamic-state.

[9] The estimates in this scenario are based on a scenario in a 2004 study. To read more on how the scenario was modeled, together with other RDD, nuclear terrorism, and nuclear weapon accident scenarios in India and in Pakistan, see, Kishore Kuchibhotla and Matthew McKinzi, "Nuclear Terrorism and Nuclear Accidents in South Asia," in Michael Krepon and Ziad Haider, eds., *Reducing Nuclear Dangers in South Asia* (Washington, DC: Stimson Center, 2004), 17-44.

Lahore, Pakistan[10]
Approximately one month after India suffered an RDD non-state actor attack, Lahore is hit. This time, the terrorists target a truck transporting 200,000 Curies (180 grams) of Cobalt-60. They fire shoulder-launched missiles at the truck carrying the radioactive material while simultaneously driving a petroleum tanker into it. The resulting fire and ensuing blast result in 70 initial casualties. The radioactive plume contaminates a large sector of Lahore near the Ravi River. Hospitals are unprepared for the influx of those injured in the blast, exposed to radiation, and suffering from severe anxiety. Some experts quoted in media accounts speculate that over the next decade, as many as 160 people in the exposed population could die of cancer likely related to radiation effects. Other media accounts, however, put expected long-term fatalities in the hundreds. Television news and talk shows are full of street interviews with Lahore residents and nearby farmers also worried about agricultural costs from ground contamination and contamination of the Ravi River. It is unclear who is behind the attack.

Panel 1 Summary: RDD Attack

Participants agreed that the RDD scenario was a high probability, but relatively low consequence event. Although the RDD attack would present short- to medium-term challenges, mainly acute health, psychological, and economic effects, it would be mostly manageable in the long-term.

Participants suggested that the most significant short-term effect would be the impact on public physical and psychological health due to the contamination of air, land, and water. There was general agreement that emergency response plans may exist on paper in India and Pakistan, but there was low confidence regarding the coordination and implementation capacities of responsible agencies. In terms of environmental effects, decontamination that could satisfy and assure the public would be a medium-term challenge.

The economic effects would be the most significant consequence in the medium-term, participants argued, due to the large costs (including "overreaction costs") of reassuring the public through: clean up and recovery of affected areas, rehabilitation of the population, restoration of confidence in safety and food security, and resumption of tourism and business travel. Extended health impacts of radiation could require investments in new medical equipment/facilities, which would be a long-term economic challenge for the state.

With respect to political effects, there was debate among participants regarding whether Indian officials would blame Pakistan for the attack in the short-term, either owing to historical suspicions or in order to deflect blame from the state. Some argued that once a similar attack took place in Pakistan, it could open up room for joint Indo-Pakistan efforts in the medium-term towards decontamination, intelligence sharing, investigation of the source of the radioactive materials, and measures to secure radiological materials.[11] Participants spent less time considering the possibility of an insider threat/accident, and the impact that would have on public trust in the state's capability to ensure security, or perceptions of international actors.

[10] The estimates in this scenario are based on a scenario in a 2007 study by a Director of Transport and Waste Safety in the Pakistan Nuclear Regulatory Authority. Abdul Mannan, *Preventing Nuclear Terrorism in Pakistan: Sabotage of a Spent Fuel Cask or a Commercial Irradiation Source in Transport* (Washington, DC: Stimson Center, 2007), 25-28.
[11] The likelihood of two synchronized RDD attacks in India and Pakistan that would abet such cooperation is quite low, but the scenario helps reveal that if mutual vulnerability is perceived, it can create the conditions for joint cooperation rather than acrimony and blame-shifting.

Scenario 2: Nuclear Plant Accident

Nuclear plants are vulnerable to a host of potential accidents. These can be caused by mishaps at the site of a nuclear reactor or external factors, such as flooding or an earthquake. The nature of accidents at nuclear reactors is affected by a variety of factors, including the reactor type. The first scenario involves a civilian nuclear power plant under International Atomic Energy Agency (IAEA) safeguards. The second models an accident in a storage tank of a reprocessing plant not under international safeguards. The incidents described occur independently, as if in parallel universes.

Karachi, Pakistan

A 9.2 magnitude earthquake occurs on the Chaman Fault, off Pakistan's Makran Coast.[12] Municipal authorities, national and provincial disaster management teams, and the military receive word from the Pakistan Atomic Energy Commission (PAEC) that an accident caused by the earthquake has occurred at the 1,100-megawatt pressurized water reactors—Karachi-2 (K-2) and Karachi-3 (K-3) at the civilian Karachi Nuclear Power Complex (KNPC). The result is a core meltdown and a spent fuel pool fire. [13]

Unfavorable wind conditions push a radioactive cloud towards Karachi. Authorities are unable to effectively implement the 15-kilometer emergency evacuation zone around the KNPC in time.[14] Public panic and attempts at self-evacuation clog roadways and lead to 25 deaths unrelated to any radiation. Most residents are unaware of the importance of initially sheltering in place. Through both direct inhalation of the radioactive aerosol and cloudshine (radiation from the plume of radioactive aerosols emitted from K-2), Karachi's residents begin to experience the early symptoms of radiation exposure: vomiting, headaches, fevers, and diarrhea.[15] In the immediate aftermath of the disaster, there are insufficient supplies of potassium iodine tablets, and some experts quoted in media accounts estimate that the exposed population, especially children, will be diagnosed at increasing rates with likely related

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[12] For evidence of the possibility of such a high magnitude earthquake occurring in the Makran subduction zone see. Gemma L. Smith, Lisa C. McNeill, Kelin Wang, Jiangheng He, and Timothy J. Henstock, "Thermal Structure and Megathrust Seismogenic Potential of the Makran Subduction Zone," *Geophysical Research Letters* 40, no. 8 (2013): 1528-1533; Also see, Roger Bilham, Sarosh Lodi, Susan Hough, Saria Bukhary, Abid Murtaza Khan, S. F. A. Rafeeqi, "Seismic Hazard in Karachi, Pakistan: Uncertain Past, Uncertain Future," *Seismological Research Letters* 78, no. 6 (2007): 601–613.

[13] See A. H. Nayyar and Zia Mian, "Hidden Dangers," *Dawn*, August 13, 2016; Richard Stone, "Spent Fuel Fire on U.S. soil could Dwarf Impact of Fukushima," *Science Insider*, May 24, 2016, http://www.sciencemag.org/news/2016/05/spent-fuel-fire-us-soil-could-dwarf-impact-fukushima; Richard Stone, "Near Miss at Fukushima is a Warning for U.S., Panel says," *Science Insider*, May 20, 2016, http://www.sciencemag.org/news/2016/05/near-miss-fukushima-warning-us-panel-says; William J. Broad and Hiroko Tabuchi, "In Fuel-Cooling Pools, a Danger for the Longer Term," *The New York Times*, March 15, 2011; and Frank N. von Hippel and Michael Schoeppner, "Reducing the Danger from Fires in Spent Fuel Pools," *Science and Global Security* 24, no. 3 (2016): 141-173.

[14] PAEC reportedly has such a plan. (Hoodbhoy, Pervez, Mian, Zia, and Nayyar, A.H. "The Nuclear Shadow Over Karachi," *Newsweek*. March 22, 2014, 27-28.) However, experts maintain that the relevant government entities did not take proper precautions when granting approval for the China National Nuclear Corporation to develop reactors about 20 kilometers from Karachi: "Evacuating Karachi would be impossible in the event of a serious nuclear accident, whether it is from an earthquake and tsunami like at Fukushima or from operator error like at Chernobyl." The 30-kilometer radius, used by authorities at Chernobyl and Fukushima, encompasses nearly the entire city of Karachi. Zia Mian and A.H. Nayyar, "Karachi Nuclear Reactors: The Environmental Watchdog that Did Not Bark," *The Third Pole*, April 7, 2015.

[15] Christodouleas, John P., Robert D. Forrest, Christopher G. Ainsley, Zelig Tochner, Stephen M. Hahn, and Eli Glatstein, "Short-Term and Long-Term Health Risks of Nuclear-Power-Plant Accidents," *New England Journal of Medicine* 364, no. 24 (2011): 2334–41.

cancer. Young, infirm, and elderly residents are disproportionately affected,[16] and Karachi's low-income residents are the most vulnerable.

Reeling from an unfortunate confluence of unlikely events, Pakistan begins to manage the disaster with forced evacuation out to 110−170 km and voluntary evacuation out to 200-250 km.[17] Meanwhile, surface and groundwater contamination continue to spread to over 200km from the reactor site. In interviews with media, evacuees express concern about future dangers and the success of decontamination efforts, vowing they will not return for years.

Kalpakkam, India[18]
An unfortunate confluence of safety failures in venting and cooling leads to a chemical explosion in one of the high-level waste tanks that hold the liquid waste streams produced at the Kalpakkam Reprocessing Plant.[19] The tank ruptures and, despite being located in an underground vault, releases a plume of radioactive material (mostly cesium-137). An already sensitive local population is angered to discover an accident has occurred, and both Indian and Sri Lankan media report widely on the incident, reflecting on past accidents.[20] Public panic and attempts at self-evacuation amidst government uncertainty about wind conditions result in 25 deaths unrelated to any radiation.

Unfavorable wind conditions push a radioactive cloud southeast towards Sri Lanka. Indian authorities are unprepared to effectively implement an emergency evacuation zone of 30km around the plant in time. Most residents are unaware of the importance of initially sheltering in place. Through direct inhalation of radioactive materials, residents begin to experience the early symptoms of radiation exposure: vomiting, headaches, fevers, and diarrhea.[21] In the immediate aftermath of the disaster, there are insufficient supplies of potassium iodine tablets, and some experts quoted in media accounts estimate that the exposed population, especially children, will be diagnosed at increasing rates with likely related cancer. Young, infirm, and elderly residents are disproportionally affected.[22]

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[16] Leppold, C., Tanimoto, T., & Tsubokura, M, "Public Health after a Nuclear Disaster: Beyond Radiation Risks," *Bulletin of the World Health Organization* 94, no. 11 (2016): 859–860.

[17] For a full study of such an event at Pakistan's Chashma nuclear power plant, including assessments of how the core melts down and its radioactive inventory is released into the atmosphere, together with environmental and human radiation costs, see Zia Mian and A.H. Nayyar, *Pakistan's Chashma Nuclear Power Plant: A Preliminary Study of some Safety Issues and Estimates of the Consequences of a Severe Accident*, SDPI, Monograph Series #11 (1999).

[18] The details from this scenario are taken from a detailed study (including estimated fatalities) conducted on a chemical explosion at the Kalpakkam Reprocessing Plant. M.V. Ramana, A.H. Nayyar, and Michael Schoeppner, "Nuclear High-level Waste Tank Explosions: Potential Causes and Impacts of a Hypothetical Accident at India's Kalpakkam Reprocessing Plant," *Science and Global Security* 24, no. 3 (2016): 174-203.

[19] "In addition to plutonium and uranium, reprocessing produces liquid waste streams. In India, liquid waste streams are classified as low, intermediate (or medium), and [high level waste] depending on the radioactive level or concentration." Ramana, Nayyar, and Schoeppner, "Nuclear High-level Waste Tank Explosions," 176-77.

[20] India has a long history of public engagement in discussions of dangers surrounding nuclear power and has had accidents in the past. See for example, M.V. Ramana and Ashwin Kumar, "'One in Infinity': Failing to Learn from Accidents and Implications for Nuclear Safety in India," *Journal of Risk Research* 17, no. 1 (2014): 23-42; and Raminder Kaur, "Nuclear Power Vs. People Power," *Bulletin of Atomic Scientists Online*, July 9, 2012.

[21] Christodouleas, John P., Robert D. Forrest, Christopher G. Ainsley, Zelig Tochner, Stephen M. Hahn, and Eli Glatstein, "Short-Term and Long-Term Health Risks of Nuclear-Power-Plant Accidents," *New England Journal of Medicine* 364, no. 24 (2011): 2334–41.

[22] Leppold, C., Tanimoto, T., & Tsubokura, M, "Public Health after a Nuclear Disaster: Beyond Radiation Risks," *Bulletin of the World Health Organization* 94, no. 11 (2016): 859–860.

India and Sri Lanka begin to manage the disaster with forced and voluntary evacuation zones. Meanwhile, contamination continues to spread from the reactor site—particularly into the Bay of Bengal. In interviews with media, evacuees express concern about future dangers and the success of decontamination efforts, vowing they will not return for years.[23]

Panel 2 Summary: Nuclear Plant Accident

To the surprise of some observers, participants generally assessed the nuclear plant accident to be the scenario that posed the most devastating consequences in the near-, medium-, and long-terms, even compared to a limited nuclear exchange. This was due to the scenario's estimated scale, potential spillover or chain reactions, duration, and trans-border effects.[24] Across domains, participants agreed that the economic strain caused by the accident would be severe. Examples of these effects included: a supply and demand mismatch creating a food security crisis; disproportionate health costs for women and children; and drastic demographic shifts from mass internal displacement and migration.

Panel discussion indicated bilateral and third-party cooperation would likely be necessary—and perhaps more welcome than in other scenarios. With respect to domestic stakeholders, participants suggested that an accident at a nuclear facility in Pakistan would likely necessitate the military's assumption of major government functions but could overextend it and/or exacerbate civil-military relations. A similar disaster in India could also prompt greater civilian and military coordination or friction. In both countries, participants suggested that erosion in state trust could potentially lead to non-state actors filling the gap to provide public services in poorly governed localities. Interestingly, some participants indicated that weather conditions surrounding the Karachi scenario might necessitate consequence management cooperation and coordination between India and Pakistan, perhaps prompting new disaster-oriented, bilateral confidence-building measures.

A final key theme highlighted by participants during the nuclear plant accident panel was information challenges. In the immediate aftermath of a nuclear facility accident, a prompt and effective evacuation of the affected area would be difficult to execute and enforce. Conflicting messages from electronic and social media communication channels sent by official and unofficial sources would likely complicate response efforts, impacting public awareness of time-sensitive health information and evacuation and relocation options.

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[23] Another interesting nightmare scenario to consider would be an accident at Kudankulam Nuclear Power Plant in Tamil Nadu, even closer to Colombo. During the 2004 Indian Ocean tsunami flooding, a reactor at the Kalpakkam Atomic Energy Plant was shut down. By the 2011 Fukushima accident, the reactors at Kalpakkam were still vulnerable. A 2011 Indian Atomic Energy Regulatory Board committee recommended, among other changes, that design improvements be made on the power plants in Kalpakkam. "Indian Nuclear Review Selects Improvements," *World Nuclear News*, September 6, 2011. For a brief study of the impact of the 2004 Indian Ocean tsunami's effect on the Madras Nuclear Power Plant in Kalpakkam, Tamil Nadu, see Sobeom Jin, "2004 Indian Ocean Tsunami on the Madras Nuclear Power Plant, India," paper presented at Transactions of the Korean Nuclear Society Spring Meeting, Chuncheon, Korea, May 25-26, 2006, available at https://www.kns.org/kns_files/kns/file/127%C1%F8%BC%D2%B9%FC.pdf.

[24] This may owe to some motivated bias and/or the very narrow design of the workshop's limited exchange scenario. Future work would require sensitivity analysis by varying the intensity of the scenario.

Scenario 3: Nuclear Weapons Accident

Nuclear weapons accidents are a piece of every nuclear-armed nation's history. As the oldest creator of nuclear weapons, the U.S. has a particularly rich catalogue of declassified U.S. weapons accidents.[25] Most involve aircraft or missile delivery vehicles.[26] The nature—and range of consequences—of nuclear weapons accidents varies widely. The following scenario focuses on an accident in which even "one-point safe" warheads are vulnerable. The incident involves a conventional explosion but no nuclear yield.

Sketchy news and social media reports surface to reveal that a fire broke out at Ambala Air Force Station (Haryana, India), where nuclear weapons are reportedly stored.[27] While India still publicly declares that its weapons are disassembled, the Prime Minister's Office had given secret authorization to maintain some of its nuclear forces in an assembled state after a series of escalating tensions on its eastern and western borders to ensure higher readiness for certain contingencies.[28] Some suspect the fire may have been electrical and that, due to shoddy fail-safes and a breakdown in standard operating procedures, detection of the fire and the subsequent response to put it out was substantially delayed. As a result of the fire, the shell of chemical high explosives surrounding the core of plutonium in a stored nuclear warhead detonates, resulting in the spontaneous fission of the atoms and a "fizzle" with no nuclear yield.[29]

Details are uncertain even among civil and military leadership with mixed internal and external messaging about what exactly has happened and what will be publicly communicated.[30] In the immediate aftermath, there is no official acknowledgement of the incident being nuclear. Authorities invoke secrecy for national security concerns, but, within the first week, leaks to the media combined with some open-source scientific estimations by non-governmental organizations seem to suggest approximately 1kg of the plutonium was converted to a respirable aerosol which was released into the atmosphere in a plume. Wind velocity was a disaster management nightmare, blowing the aerosolized plutonium directly over the nearby city of Chandigarh, Haryana. Evacuation efforts remain inchoate and haphazard because of continued uncertainty among authorities and resulting lack of

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[25] Department of Defense, *Narrative Summaries of Accidents Involving U.S. Nuclear Weapons 1950-1980*, available at, https://nsarchive.files.wordpress.com/2010/04/635.pdf; and Eric Schlosser, *Command and Control: Nuclear Weapons, the Damascus Accident, and the Illusion of Safety* (London, UK: Penguin, 2013).

[26] R. Rajaraman, M.V. Ramana, and Zia Mian, "Possession and Deployment of Nuclear Weapons in South Asia: An Assessment of Some Risks," *Economic and Political Weekly* 47 no. 25 (2002): 2462.

[27] For recent, open-source estimates of India's nuclear forces and possible deployment locations see, Hans M. Kristensen and Robert S. Norris, "Nuclear Notebook: Indian Nuclear Forces, 2017," *Bulletin of Atomic Scientists* 73:4 (2017): 206.

[28] Experts believe this may have already happened to some degree as India moves towards "canisterized" systems. See Vipin Narang, "Five Myths About India's Nuclear Posture," *The Washington Quarterly* 36 no. 3 (2013): 148-149.

[29] For historical examples of this type of weapons accident scenario see, "November 4, 1958/B-47/Dyess AFB, Texas," Department of Defense, *Narrative Summaries of Accidents Involving U.S. Nuclear Weapons 1950-1980*, 14; David Stiles, "A Fusion Bomb over Andalucia: U.S. Information Policy and the 1966 Palomares Incident," *Journal of Cold War Studies* (2006), 8, (1) 49-67; and Lind O.C. et al. "Science of the Total Environment: Characterization of U/Pu particles Originating from the Nuclear Weapon Accidents at Palomares, Spain, 1966 and Thule, Greenland, 1968," *Science of The Total Environment* (2007), 376, (1-3): 294-305.

[30] For examples of this kind of initial confusion, see reporting on the 1985 Bhopal gas disaster and former Foreign Secretary Shyam Saran's assessment of official communications during the 2016 Pathankot attack. Robert Reinhold, "Disaster in Bhopal: Where does the blame lie?" *New York Times*, January 31, 1985. Shyam Saran, "Organizing for Crisis Management: Evaluating India's Experience in Three Case Studies," *Investigating Crises: South Asia's Lessons, Evolving Dynamics, and Trajectories* (Washington, D.C.: Stimson Center, 2018), 57-73.

intragovernmental coordination. Initial expert estimates quoted in media accounts assess that, as a result of exposure during the passage of the plume, together with further contamination when plutonium deposits on the ground are later re-suspended in the air, the exposed population has likely inhaled approximately 1640 mg of plutonium, which could result in up to 5,000 likely related cancer deaths in the ensuing years.[31]

Panel 3 Summary: Nuclear Weapons Accident

The panel discussion on a nuclear weapons accident highlighted the attribution process and timeline as pivotal factors in the management of effects for such an event. While participants confirmed that India would be obligated to notify Pakistan about a nuclear weapons accident per their bilateral agreement, they debated the likelihood and relative incentives for compliance. Participants observed substantial incentives for the government to cast the accident as a hostile act of sabotage by an adversary but acknowledged the high risk of a commitment trap compelling India to "respond" to sabotage of a nuclear weapon. The delayed health and environmental effects of this scenario (e.g. long-term upticks in cancer rates; dispersed contamination affecting agriculture) were suggested as potential factors in potential government communication strategies.

At the domestic level, some speculated that a nuclear weapons accident could induce the Indian military to undertake extensive internal reviews, reform standard operating procedures, and formulate and rehearse disaster responses. Most participants doubted this would precipitate any electoral consequences or formal public inquiry unless the accident were attributed to corruption or negligence. At the same time, the accident would afford an opportunity for exploitation by certain political or bureaucratic actors to challenge the custodianship and organizational prerogatives of rival agencies.

Two possibilities were considered with respect to China's response as a key third party: 1) China would refrain from responding unless there were a kinetic Indian response to a perceived act of Pakistani sabotage; 2) China would exploit the accident to critique India's record of nuclear stewardship and prevent it from fully joining the Nuclear Suppliers' Group. The latter response could have costly economic implications for India's nuclear industry.

Scenario 4: Limited Nuclear Exchange[32]

Amidst rising tensions and conflict, a perceived grievous provocation by India crosses one of Pakistan's 'red lines.' In response, the Pakistan National Command Authority authorizes ground-

[31] The numbers for the weapon's plutonium oxidizing and becoming aerosolized, dispersed, and inhaled by people in this scenario, along with the resulting fatalities, are based on estimates and calculations done for a mirror simulation study on the edge of an urban center (15,000 people per square kilometer). Most of the respirable plutonium released in the air wouldn't actually be inhaled when the plume is blown over Chandigarh; people would breathe it in over time as particles on the ground in the contaminated area are re-suspended in the air. Zia Mian, M. V. Ramana, and R. Rajaraman, *Risks and Consequences of Nuclear Weapons Accidents in South Asia*, PU/CEES Report No. 326 (Princeton, NJ: The Center for Energy and Environmental Studies, Princeton University, 2000).

[32] This scenario is perhaps the most difficult with regards to the consideration of effects. This is due in no small part to the fact that the world has never seen a state-on-state nuclear exchange. We have kept the scenario simple in order to facilitate discussions that focus on the post-booms scenario—not on escalation or de-escalation. The details of how this scenario unfolds are less important than thinking through general impacts and possible responses and management actions. For a good overview of the impacts of a nuclear war on the subcontinent see, Matthew McKinzize, Zia Mian, A.H. Nayyar, and M.V. Ramana, "What Nuclear War Could Do to South Asia," in *Confronting the Bomb: Pakistani and Indian Scientists Speak Out*, ed. Pervez Hoodbhoy (Oxford: Oxford University Press, 2013), 267-276.

launched Babur cruise missile strikes on Sarsawa Air Station in Uttar Pradesh.[33] In newspaper editorials and TV interviews, experts unofficially estimate that two 12-kiloton airbursts and the resulting fireball, air blast, and initial acute radiation have killed 7,890 of the residents and injured 47,180.[34] Everyone within an air blast radius (20 psi) of .65 km (or 1.31 km^2) is killed, and concrete buildings are destroyed. Transport routes, power sources, and other critical infrastructure in the blast radius are also destroyed or badly damaged. Surviving aircraft and the base have limited operability.

In response, India's Nuclear Command Authority's Political Council authorizes ground-launched Nirbhay cruise missile strikes on Pakistan Air Force Base Samungli near Quetta, Baluchistan. In newspaper editorials and TV interviews, experts unofficially estimate that two 12-kiloton airbursts and the resulting fireball, air blast, and initial acute radiation have killed 8,770 of the residents and injured 47,350.[35] Everyone within an air blast radius (20 psi) of .65 km (or 1.31 km^2) is killed, and concrete buildings are destroyed.[36] Transport routes, power sources, and other critical infrastructure in the blast radius are also destroyed or badly damaged. Surviving aircraft and the base have limited operability.[37]

Crisis management mechanisms in South Asia and intercession by the United States and China keep the conflict from escalating any further. The limited nuclear exchange ends, but the nuclear taboo has been broken.[38]

Panel 4 Summary: Limited Nuclear Exchange

Perhaps not surprisingly, discussions of the limited nuclear exchange scenario concentrated more on strategic and geopolitical consequences than on other types of effects. Health (including long-term impacts on physical and mental public health), socioeconomic, and environmental effects proximate to the blast locations would be devastating in the near-term, but a number of participants argued that these effects would be limited and manageable in the long-run for both countries.

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[33] Estimates for this scenario are based on simulations in NukeMap. Wellerstein, Alex, "NukeMap," College of Arts and Letters, Stevens Institute of Technology, 2012-2017. These simulations rely on data from Google and thus running the same simulation can yield somewhat varied results as new data becomes available. For a more qualitative simulation, see Andrew Giesey, Khan, Feroz Hassan., Morgan, Ryan and Wueger, Diana. "South Asian Stability Workshop 2.0: A Crisis Simulation Report," Naval Postgraduate School, CCS, PASCC, 2016.

[34] Alex Wellerstein, NukeMap (2012-2018), http://nuclearsecrecy.com/nukemap/?t=6fc0704798cab499947c212df3c06380.

[35] Wellerstein, http://nuclearsecrecy.com/nukemap/?t=24c25e96b648d9a982547aa1bed0a31c.

[36] For both scenarios, radiation public health effects depend on radiation dose and medical treatment, with dying "acute effects alone" taking "between several hours and several weeks." In the broader air blast radius (5psi) of 1.59 km (or 7.98km^2), there are additional fatalities, everyone sustains injuries and third-degree burns, and most residential buildings are destroyed. Wellerstein.

[37] The casualty estimates for both attacks in this limited nuclear exchange scenario are meant to reflect possible civilian casualties but also military casualties for stationed squadrons and base personnel. The possibility of surviving aircraft assumes some sealed, hardened aircraft shelters.

[38] On the logic that drives limited nuclear options see, George H. Quester, *Nuclear First Strike: Consequences of a Broken Taboo* (Baltimore, MD: The Johns Hopkins University Press, 2006), 34-35; Brendan Green and Austin Long, "The Geopolitical Origins of US Hard-Target-Kill Counterforce Capabilities and MIRVs," *The Lure an Pitfalls of MIRVs: From the First to the Second Nuclear Age*, Ed. Michael Krepon, Travis Wheeler, and Shane Mason, (Washington DC: Stimson Center, 2016), 35; William Burr, "The Nixon Administration, the SIOP, and the Search for Limited Nuclear Options, 1969-1974," National Security Archive Electronic Briefing Book No. 173, November 23, 2005, https://nsarchive2.gwu.edu/NSAEBB/NSAEBB173/#1; and Michael Krepon, "Limited Nuclear Options," *Arms Control Wonk*, July 14, 2010.

Some suggested the described limited nuclear exchange scenario could invite immense international pressure on both countries, while others thought it would be perceived as a strategic success demonstrating the viability of limited nuclear war and shoring up the credibility of general deterrence. There was slightly more agreement that the event would highlight weaknesses of existential deterrence, irreversibly impacting nuclear stances in South Asia and potentially elsewhere by likely prompting a more aggressive posture.

There was no consensus among participants on the nature, direction, and extent of long-term reputational effects following a limited nuclear exchange. Many participants predicted that both countries would suffer international reputational damage—Pakistan for using nuclear weapons first and India for retaliating—and that the two states would be "re-hyphenated" in the eyes of the international community. There were mixed assessments of third-party roles, including doubt about preparedness of the U.S. and other major powers to help manage humanitarian and other resulting crises. Participants suggested China would play a larger role in the aftermath of the crisis due in part to the high likelihood of casualties including Chinese residents in Pakistan, and agreed that Beijing would not abandon Islamabad as an economic and strategic partner. Impacts and responses on neighboring countries were likewise a point of uncertainty, including neighboring Iran and South Asian states in the Indian Ocean Region.

Overall, the effects of a limited, India-Pakistan nuclear exchange were perhaps the most difficult of the workshop's four scenarios to scope and grapple with in terms of the major initial, as well as second- and third-order, series of effects. While participants seriously engaged the scenario, several scholars noted it to be the most implausible because of its significant departure from both countries' declared doctrines. This consideration of effects is difficult because in order for the hypothetical scenario to unfold as described, so many other contextual features that condition effects would also be altered, rendering inferences from the present quite challenging.[39]

[39] If true, this could constitute a violation the assumption of "information equivalence." See Allan Dafoe, Baobao Zhang, and Devin Caughey, "Information Equivalence in Survey Experiments," *Political Analysis* 26 (4), October 2018, pp. 399-416.

Findings

Major Takeaways

Breadth Without Comparison. Participants identified a variety of long-term downstream effects. Some of the more interesting consequences resulted from medium- to long-term effects on demographics such as internal displacement, fertility rates, and localized brain drain. However, most discussions did not attempt to explicitly compare or rank-order different types of effects (for example, evaluating how economic effects stacked up versus strategic effects). Priority ranking of effects and related management challenges may be a useful exercise in future.

No Paradigm Shift. In general, there was an appreciation that the different types of risks could be thought of as negative externalities of nuclear weapons or nuclear power. Should an incident occur, it would raise the cost of but not fundamentally alter the approach to the general utility of nuclear weapons and power. As one participant put it, despite contemplation of these major black swan events, few if any workshop participants anticipated a paradigm shift (or major discontinuity in policy). However, after such a major nuclear event, some shakeups of responsibility or oversight between government agencies were considered plausible as well as shifts in doctrine (e.g. more active and explicit pursuit of counterforce targeting).

Human Security Secondary. In terms of the time and focus they commanded in discussions, health and environmental effects did not weigh as heavily on the conversation, perhaps because they pose diffuse and dispersed rather than concentrated effects and might be treated as indistinguishable from preexisting issues such as intense pollution and particulate matter. Alternately, this may have been because they created a new equilibrium or "new normal" that would ultimately be accepted and managed by the general populace. On average, these effects were expected to follow a sin curve. For instance, with the economy, there would be a significant dip, then a resurgence, followed by a return to either a new equilibrium or growth curve—generally lower than the equilibrium prior to the event.

Obscured Challenges and Long-term Consequences. A key challenge in the workshop was identifying more obscure and long-term effects of scenarios. Discussion tended to focus on the finite, near-term nuclear/radiological aspects of the scenarios and discount the complex and dynamic context that would complicate responses such as: physical impediments like rubble, debris or pre-disaster infrastructure limitations; social pathologies; organizational and political obstacles; chronic security force demands; and emotional or psychological tolls. Some of these factors emerged in small-group discussions but remained largely underdeveloped and unexplored.[40]

Tensions & Debates

Event Costs vs. Overreaction Costs. A counterintuitive theme that regularly made its way into discussions (in part, seeded by one of the subject matter expert participants) was that, at least in terms of economic effects, overreactions to the nuclear event might turn out to be costlier than the immediate effects of the event itself. Emergency consequence mitigation efforts can exceed actual needs and create perverse lock-in effects and new path dependencies. Ultimately, national economies

[40] This underexplored area may be a result of simple time constraints of the workshop and/or the narrow parameters of the scenarios presented.

would reach new equilibria, and longer-term opportunity costs would be internalized but perhaps not appreciated or felt.

Secrecy vs. Transparency. Another tension discussed that states would have to grapple with was the political and security incentives for secrecy versus the governance and human security impulses for transparency. This tension is driven by different theories of how to effectively manage a crisis and restore stability and public confidence. While providing regular updates and complete information after an event can help to reduce public panic or overreactions to the event, local and national officials might seek to restrict information flow in an attempt to buy time, reduce vulnerability and panic, and retain control of their institutional prerogatives. A similar debate played out over whether and when India and Pakistan might be transparent with each other over accidental or non-state-triggered nuclear events, with no real consensus.

Blame Shifting? States already absorb some blame for poor responses to natural disasters, but the state would face even more intense blame for events triggered by human error. If the government (particularly a weak or coalition government) could not control media narratives in order to contain this public backlash, officials could seek to instead frame unintentional events as an act of sabotage by an adversary, thereby risking a commitment trap. Some participants suggested there may even be incentives to "wag the dog" and purposefully engage in diversionary military action in the wake of such an accident.

Military Stabilizer vs. Military Overextension. Participants agreed the military would play a key first-and-last-responder role in managing the effects of scenarios in both countries (especially for a weapons accident or exchange). A key tension identified was that disaster management duties would compete with strategic and operational demands on military readiness and deterrence mandates. Drawing the military in makes all scenarios strategic.

Concern with International Reactions: China > West. Concern for international reactions was mixed and quite revealing. Little consideration was afforded to the role of crisis management by China or the United States. However, participants did pay a lot of attention to the reaction of China and its subsequent impact on South Asian economies. Opinions varied as to whether after a nuclear event involving the accidental or deliberate use of weapons China would: (1) act with greater caution with respect to investments or personnel in the region; (2) actively pressure and/or restrain Pakistan; or (3) shield and/or aid Pakistan while leveraging the incident to stymie India's international institution aspirations (e.g. NSG, UNSC). There was considerably less if any attention paid towards the reputational or prestige costs amongst Western observers or international nonproliferation institutions—namely the United States, Western Europe, and institutions like the Conference on Disarmament and the International Atomic Energy Agency.

Pessimism, and *Some* Optimism. Many of the scenarios contained the possibility of both conflict or cooperation between India and Pakistan, as well as learning from and repetition of past errors (e.g. botched disaster management). This suggests the political environment prior to the event will be crucial to shaping the geopolitical effects. A small minority thought the violation of the nuclear taboo on nuclear weapons use would have meaningful effects. Instead, most participants argued that the taboo is far weaker than assumed by some scholars and practitioners.[41] Some participants argued that once a particular event occurs, it is more likely to reoccur (reload or copycat effect). This argument was made particularly in reference to events resulting from intentional acts (radiological terror attack, sabotage of nuclear weapons or nuclear facility, or a nuclear exchange). Even though the scenarios involved serious consequences, many participants offered assessments of silver lining opportunities for learning, shared risk assessments, and new bilateral or regional confidence-building measures that could ensure future prevention.

[41] This argument is consistent with some experimental findings. See Daryl G. Press, Scott D. Sagan, and Benjamin A. Valentino "Atomic Aversion: Experimental Evidence on Taboos, Traditions, and the Non-Use of Nuclear Weapons," *American Political Science Review*, 107 (1), February 2013: 188-206. r

Conclusion

The key accomplishments of this workshop were twofold. First, the workshop facilitated substantive analytical discussion on nuclear events and offered a replicable framework for facilitating similar research and discussions in other domestic, regional, and international fora.

Second, the workshop generated some new insights on a considerably understudied area of consequence management in a nuclear environment. New research and discussions of management challenges for nuclear disasters are merited—both at a multilateral level and in applied regional contexts. Such engagements can allow analysts and practitioners to weigh crucial considerations, inform planning and preparation efforts, and create space for considering potential transnational effects of such black swan events.

Future Stimson Center work will seek to build upon these findings and participant contributions of this workshop. The next Stimson workshop will combine the research design of this first workshop with additional interactive simulation exercises or decision/portfolio games. The follow-on workshop will consider both challenges and tradeoffs but also priorities for key stakeholders in the aftermath of black swan nuclear events.

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