THE HENRY L.
STIMSON CENTER

Reducing Nuclear Dangers in South Asia

Michael Krepon and Ziad Haider, editors

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About the Authors

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About the Stimson Center's South Asia Programming

The Henry L. Stimson Center's programming on South Asia began in 1991. Programming activities are designed to stabilize and reduce nuclear dangers on the subcontinent; facilitate positive movement on the Kashmir issue; and promote regional stability and normal relations between India and Pakistan.

To further these objectives, the Stimson Center employs several programming tools. We publish a significant body of work on risk reduction, confidence building, and reconciliation that has been utilized by decision makers, researchers, students, and military officers. Project publications include *Crisis Prevention, Confidence Building, and Reconciliation in South Asia* (St. Martin's Press, 1995)*; Global Confidence Building: New Tools for Troubled Regions* (St. Martin's Press, 1999)*;* and *Nuclear Risk Reduction in South Asia* (Palgrave Macmillan, forthcoming in 2004). In addition, the Stimson Center has published numerous reports and essays on South Asia which can be accessed on our website (http://www.stimson.org). Annual fieldtrips to India, Pakistan, and Kashmir inform the Stimson Center's publications and program initiatives. The Stimson Center also has created a Visiting Fellows program, which has hosted over 65 Pakistani and Indian journalists, academics, researchers, and military officers. The goals of our Visiting Fellows program are to increase mutual understanding, improve analytical capabilities, and to promote creative, problem-solving ideas. The Stimson Center also convenes Track II workshops on nuclear risk reduction and escalation control.

Funding for the Stimson Center's South Asia programming is provided by the Nuclear Threat Initiative and the Carnegie Corporation of New York. Funding for the Visiting Fellows program is provided by the National Nuclear Security Administration of the United States Department of Energy.

South Asia programming is directed by founding president Michael Krepon. Ziad Haider serves as the research assistant to the project.

About the Henry L. Stimson Center

Founded in 1989, the Henry L. Stimson Center is a not-for-profit policy institution dedicated to enhancing international peace and security through rigorous, non-partisan analysis and results-oriented outreach. Initially focused on arms control, the Center's research agenda has expanded to include a broad range of critical security issues. Reducing the dangers from nuclear, chemical, and biological weapons remains an enduring commitment. Stimson research also focuses on strengthening the institutions that play significant roles in international peace and security – from the United Nations, to the State Department, to the armed forces. In addition, the Center works actively with Congress through our *Security for a New Century* seminar series.

The Center draws inspiration from the life and work of Henry L. Stimson, whose appointments included Secretary of War for Presidents William Howard Taft, Franklin Roosevelt, and Harry Truman, and Secretary of State for President Herbert Hoover. He believed strongly in "*pragmatic idealism,*" the notion that progress toward peace is only possible through practical steps and strong US engagement in the world. Although Henry Stimson could not have anticipated many of the challenges that confront the world a half-century after his passing, we believe that his practical, non-partisan approach to issues remains as relevant today as in his lifetime.

List of Abbreviations

CBM	Confidence Building Measures
DGMO	Director-General of Military Operations
DSTO	Database on Nuclear Smuggling, Theft and Orphan Radiation Sources
DTRA	Defense Threat Reduction Agency
EMP	Electromagnetic Pulse
EPA	Environmental Protection Agency
FSB	Russian Federal Security Services
HEU	Highly Enriched Uranium
HPAC	Hazard Prediction Assessment Capability
IAEA	International Atomic Energy Agency
IB	International Border
IIS	Institute for International Studies
LNT	Linear-No-Threshold
LoC	Line of Control
MOAB	Massive Ordinance Aerial Blast
MoU	Memorandum of Understanding
NBC	Nuclear, Biological, and Chemical
NFU	No First Use
NRC	Nuclear Regulatory Commission
RDD	Radiological Dispersal Device
REM	Roentgen Equivalent Man
TEDE	Total Effective Dose Equivalence
WMD	Weapons of Mass Destruction

Preface

I am pleased to present this new publication that provides a window into an important initiative the Henry L. Stimson Center has led over the past two years. As 2004 begins, we are witnessing a potentially significant improvement in relations between two key countries, India and Pakistan, which have struggled over the last half-century to develop "normal" ties despite the tragedies and tensions that have shaped their unique history.

The Stimson Center, with support from the Nuclear Threat Initiative and the Carnegie Corporation of New York, has worked quietly with former diplomatic, military, intelligence and academic leaders of the two countries to develop a collaborative analysis about ways to reduce the dangers associated with nuclear terrorism and nuclear accidents. The participants in these exchanges are now ready to share the fruits of this work with a larger audience.

I hope you will find this report useful and encouraging. First, it illuminates how India and Pakistan would address problems of unintended escalation arising from specific scenarios associated with nuclear terrorism and nuclear accidents. Second, it reminds us of the good will and willingness to find common ground that exists among important elements of both societies, as represented by the participants in these exchanges. Lastly, the report may prove valuable in broadening the conversation about ways to avoid unintended escalation on the subcontinent to a larger audience of interested citizens and experts in India, Pakistan, the United States and beyond. These private workshops have produced very specific recommendations for nuclear risk reduction that are now ripe for official consideration.

We are grateful to all the participants for their serious commitment to this endeavor, and hope that it will contribute in some modest way to a more peaceful and secure future for the people of these two great nations. We are also grateful to our funders who have made this work possible. In particular, my colleagues and I at the Stimson Center wish to thank Senator Sam Nunn, Charles Curtis and Joan Rohlfing at the Nuclear Threat Initiative, as well as Vartan Gregorian, Stephen Del Rosso, and David Speedie at the Carnegie Corporation for their generous support for our South Asia programming. Thanks are also due to Jane Dorsey, Ziad Haider, Michael Heller, Jessica Heller, Lisa Herskowitz, and Elizabeth Wallish for their help in shepherding this publication to print.

January 2004

Ellen Laipson
President and CEO

Introduction

Michael Krepon

Responsible nuclear stewardship demands the avoidance of crises that could lead to unintended escalation, as well as the negotiation and proper implementation of nuclear risk reduction measures. The decision by President Pervez Musharraf and Prime Minister Atal Bihari Vajpayee to resume a composite dialogue in February 2004 provides an important opportunity to demonstrate responsible nuclear stewardship. Success in this regard requires cooperative as well as unilateral measures to reduce nuclear dangers. To date, both countries have worked hard at unilateral steps. The time has come to supplement unilateral arrangements with cooperative measures.

During the hiatus in official dialogue between New Delhi and Islamabad, the Henry L. Stimson Center initiated a series of private workshops with Pakistani and Indian experts who have considerable experience in crisis management and diplomacy, military operations in peace and war, as well as intelligence collection and support to national leaders. To this mix we added Western students of Cold War experience and crisis management.

This project has had four principle objectives: (1) to consider scenarios that could result in a crossing of the nuclear threshold on the subcontinent; (2) to promote a collaborative, problem-solving engagement by Indian and Pakistani participants on how these scenarios might be prevented and, if prevention fails, how unintended escalation might be controlled; (3) to convey the substance of our work and the recommendations of our participants to senior officials in the Indian, Pakistani and US governments; (4) to place material on escalation control and nuclear risk reduction in the public domain to widen the circle of consideration and debate over these important subjects.

The participants had direct input into the scenarios we used as a basis for analysis. After much preparatory work, including field trips in Pakistan and India, our colleagues set aside skepticism and accepted as a point of departure for our collaborative analysis a scenario involving the use by a terrorist group of a "dirty" bomb. We also considered scenarios involving an accident that produced a nuclear yield, as well an ambiguous nuclear event. These scenarios are included in this publication, along with summaries of our workshop deliberations and recommendations.

We asked our participants to suspend their disbelief regarding the low probability of these events in order to consider what the ramifications might be if such events were somehow to occur, and in order to consider steps to strengthen prevention measures. Our consideration of these scenarios should not lead readers to infer a lack of faith in responsible nuclear stewardship in India or Pakistan, nor a lack of confidence in national leaders to do everything in their power to prevent horrific developments that could have spiraling and long-lasting consequences. The leaders of India and Pakistan have already demonstrated their cognizance of the consequences of any crossing of the nuclear threshold.

Our Indian and Pakistani participants deserve special thanks for collaborating analytically in ways that US and Soviet experts never did during the Cold War. We are grateful to Qazi Javed Ahmed, Shankar Bajpai, Zafar Cheema, Mahmud Durrani, Salman Haidar, Jehangir Karamat, Farrakh Khan, Feroz Khan, Shaharyar Khan, V.P. Malik, S.K. Mehra, K. Raja Menon, M.K. Narayanan, V.R. Raghavan, Rahul Roy-Chaudhury, Najmuddin Shaikh, and Saeed Uz Zafar for their participation. We shall miss Air Chief Marshal Mehra, who passed away after participating in these workshops. Our thanks also go to Peter Lavoy, Joan Rohlfing, and Scott Sagan, who provided guidance and facilitation before, during and after the workshops. The Stimson Center drew on a wider circle of US advisors in helping to design this unique programming initiative. We are grateful to Michael Crutcher, Lisa Curtis, Craig Denny, Lewis Dunn, Robert Einhorn, Jack Gill, Rose Gottemoeller, William Hatchett, Douglas Makeig, Polly Nayak, Michael Oppenheimer, George Perkovich, Caroline Russell, Teresita Schaffer, John Sigler, Scott Taylor, Michael Wasserman, and Richard Winslow.

Last, but certainly not least, the Stimson Center's work on South Asia has been greatly enhanced by outstanding research assistants. Kishore Kuchibhotla and Chris Clary were instrumental in the planning, logistics, and successful execution of the Escalation Control Project workshops. Ziad Haider has provided valuable editorial assistance.

The Stimson Center began programming on confidence building and nuclear risk reduction measures on the subcontinent in 1991. Back then, we believed that the Cold War experience in such matters would be of interest to policy makers, military leaders, teachers, students, and researchers in India and Pakistan. We understood that lessons from the Cold War could not mindlessly be transposed to South Asia, but we hoped to stimulate discussion, thinking, and writing about how the techniques and procedures applied to reduce nuclear danger and build confidence between the United States and the Soviet Union might be usefully adapted for use by India and Pakistan. A mutual learning process ensued as US advocates began to understand more clearly the complexities of the subcontinent, while strategic analysts within the region dropped reflexive opposition to concepts derived from the Cold War.

Over time, a creative synthesis began to emerge as US analysts spent more time in South Asia, and as our colleagues in the region began to appreciate more deeply the dangers associated with offsetting nuclear weapon capabilities. The old days, when Americans would confidently offer "fixes" and when South Asians would abruptly reject external prescriptions, are thankfully behind us. Substantive interactions have become possible as a result of a decade of conversations that have generated mutual respect and a common desire to learn from one another.

The much-admired skills of Indian adaptation and absorption are now being applied to western concepts of deterrence, confidence building and nuclear risk reduction. The literature on these topics is growing in depth and breadth. Differing perspectives have sparked a healthy public debate over nuclear doctrine and requirements, as well as how best to achieve strategic stability.

A parallel inquiry is underway in Pakistan, but it is mostly carried out in military circles and in unpublished writings. Consequently, outsiders are less able to assess official thinking or to question basic assumptions. Nonetheless, public declarations by government officials and senior military officers suggest that the process of synthesizing and adapting Western concepts to South Asian ground realities is well underway in Pakistan, as well as in India.

This synthesis was nurtured in "Track II" meetings, a process which is sometimes maligned, but which has periodically seeded useful ideas into official dialogue. Indeed, focused Track II deliberations are especially valuable when official dialogue is absent, or when it proceeds very slowly.

Developing professional contacts and working relationships with colleagues half-a-world away has been extremely rewarding. It is also gratifying to hear echoes of analyses nurtured by the Stimson Center emanating from capitals. This work has also been extremely frustrating. Good ideas have repeatedly been stymied by political impasses, tragic events, and the imposition of linkages between nuclear risk reduction and progress on other fronts, particularly Kashmir. During the Cold War, we joked that the United States and the Soviet Union often endorsed the same positions—but not at the same time. This maddening phenomenon is not unknown to South Asia, as well.

Much work is needed to reduce nuclear dangers on the subcontinent. The "stability-instability" paradox that was formulated in the West to characterize the dangers of nuclear deterrence is alive and well in South Asia. This paradox holds that, while offsetting nuclear capabilities might indeed prevent a full-blown conventional or nuclear war, the presence of these fearsome weapons could also encourage the use of violence at lower levels in the expectation that escalation would be contained by a mutual desire to avoid the nuclear threshold.

One fundamental premise behind the stability-instability paradox—heightened tensions and increased violence at lower levels—is beyond dispute. Kashmir has been inflamed since the advent of covert nuclear capabilities on the subcontinent, and tensions have grown even more pronounced with the demonstration of overt nuclear capabilities in 1998. The region is now experiencing crises with greater frequency and severity. One such crisis erupted into a limited war in the heights above Kargil in 1999. For almost a year after Islamic extremists attacked the Indian parliament in December 2001, over one million soldiers assumed battle-ready positions along the Kashmir divide and the international border. Despite these crises, a major conventional war has been avoided, and the nuclear threshold has not been crossed. Perhaps both tenets of the stability-instability paradox will hold true in South Asia, as was the case during the Cold War.

But without serious and sustained collaborative effort by national leaders to reduce nuclear dangers, much is being left to chance.

Western deterrence theory is now being tested in South Asia. In other publications, the Henry L. Stimson Center has presented the work of US, Indian, and Pakistani analysts considering whether the presence of offsetting nuclear arsenals is stabilizing or destabilizing on the subcontinent.[1] The Stimson Center has also delved into the likely impacts of introducing ballistic missile defenses on offensive nuclear capabilities in triangular interactions among India, China, and Pakistan.[2] Here we begin to explore the crucial question of escalation control and the nuclear option in the context of recurring crises between the governments of India and Pakistan, a significant absence of trust and reliable lines of direct communication, a wide gap in preferred outcomes on the Kashmir dispute, and continued violence in the Indian state of Jammu and Kashmir, which is called “Indian Held Kashmir” in Pakistan.

In the pages that follow, we explore security dilemmas that could lead to unintended escalation and the use of nuclear weapons. Thankfully, these nightmare scenarios did not occur during the Cold War. India and Pakistan might be similarly fortunate. But wise leadership does not depend on good fortune to avoid nuclear danger. Common sense and responsible nuclear stewardship suggest the value of considering these nightmare scenarios and adopting measures to prevent their occurrence. And if nightmares come true, measures must be considered in advance to avoid unintended escalation.

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[1] Michael Krepon and Chris Gagne (eds.), *The Stability-Instability Paradox: Nuclear Weapons and Brinksmanship in South Asia* (Washington, DC: The Henry L. Stimson Center, 2001).

[2] Michael Krepon and Chris Gagne (eds.), *The Impact of US Ballistic Missile Defenses on Southern Asia* (Washington DC: The Henry L. Stimson Center, 2002). See Chapter 5, “Missile Defense and the Asian Cascade.” in Michael Krepon, *Cooperative Threat Reduction, Missile Defense, and the Nuclear Future* (New York: Palgrave Macmillan, 2003).

Escalation Control Workshop Summaries

Executive Summary

The Henry L. Stimson Center convened two workshops to discuss escalation control and scenarios that could lead to a crossing of the nuclear threshold with Indian, Pakistani, and US participants.

The workshops underscored the importance of political context in shaping an unfolding crisis, both with respect to bilateral relations and to domestic pressures on national leaders. If verifiable efforts are underway to improve relations, escalation can be more easily controlled. If relations are frozen, the reverse is true. The workshops also underscored that there is a potential for misunderstanding and misreading signals sent between Indian and Pakistani leaders. Nuclear signaling during crises is clouded because leaders tend to send different messages to domestic, cross-border, and international audiences.

Workshop participants also concluded that declaratory nuclear doctrine, which emphasizes punishment, does not effectively address a host of contingencies that could arise, such as nuclear terrorism, the detonation of a "dirty" bomb, and nuclear accidents. In such scenarios, it might be difficult to provide national leaders with timely and accurate information about what occurred and who might be responsible.

Workshop participants concluded that the following steps would be useful, practical, and "doable" in the near term:

- **Establishment of National Risk Reduction Centers** to serve as focal points for the administration of confidence-building measures**.**
- **Missile-related measures** to formalize and properly implement the agreement concerning prior notification of missile launches; to formalize and extend the time-line for such notifications; to forgo missile flight tests in the direction of the other country; to flight test missiles only from designated test ranges; and to provide advance notification of the movement of missiles for training purposes.
- **Clarifying terminology or developing common terminology** on nuclear-related programs, deployment, and doctrine could reduce misunderstanding and increase crisis stability.
- **Leadership declarations affirming responsible nuclear stewardship** could help defuse nuclear dangers and facilitate an improvement in bilateral relations.
- **Increased awareness of nuclear dangers**, particularly with regard to the possible acquisition of nuclear materials by terrorist groups, would be advisable.

First Stimson Center Escalation Control Workshop
14-18 November 2002

Introduction

Seventeen Indian, Pakistani and US participants met at the Gorse Hill Conference Center in Woking, Surrey, from 14-18 November 2002, to discuss escalation control in South Asia. The participants agreed that consideration of the general topic of escalation control was warranted even though national leaders would certainly do their utmost to be responsible custodians of their nuclear arsenals. Participants recognized that the unexpected could happen, and that prevention is served by thinking through unlikely possibilities in advance. The group agreed to undertake a collaborative analysis of the calculus of decision that national leaders would be confronted with in the event of escalatory pressures.

The group used hypothetical scenarios as a starting point for conversation, examining the choices that would confront policymakers under certain circumstances. Highly unlikely, but not inconceivable, scenarios were tackled because of the gravity of the stakes involved. Across the spectrum of scenarios examined, the participants acknowledged two recurrent themes.

The first was that context matters. Political context shapes an unfolding crisis, both with respect to bilateral relations and domestic pressures. A new crisis between India and Pakistan that unfolds in the context of very poor bilateral relations and a breakdown of communication would be most worrisome. A triggering event in these circumstances has the potential to escalate quickly. There is a greater chance of preventing unintended escalation if bad news occurs in the context of concerted efforts by national leaders to improve bilateral relations.

Second, the participants concluded that the level of mutual understanding between India and Pakistan is currently low, making the potential for misunderstandings and unintended escalation uncomfortably high. The messages intended to be conveyed by one side were not necessarily those heard by the other. This might apply to nuclear doctrine as well as other issues, including a jointly understood, calibrated escalation ladder. In particular, the communication of "red lines"—the crossing of thresholds that could lead to nuclear escalation—has not been clear. Indeed, it may be impossible or undesirable to be completely clear about red lines.

Scenario 1: Unconventional Attacks To Limited War

Triggers

To help make the discussion of escalation control more concrete, participants examined scenarios in which acts of violence had the potential to trigger limited, conventional conflict and unintended escalation. A number of possible triggers were considered: terrorism by non-state actors, either with or without state sponsorship; infiltration at high or increased levels and step-jumps in the use of force, such as the use of helicopter gunships or fixed-wing, combat aircraft across the Line of Control (LoC) dividing Kashmir.

The participants generally agreed that a major terrorist attack on Indian soil would carry with it a strong presumption of Pakistani guilt, whether or not this were the case. A terrorist attack against New Delhi would have graver consequences than acts on terror within Jammu and Kashmir. Domestic political context matters greatly in the calculations of likely responses. Strong and weak governments might react differently to the same event. Another factor is whether a government is facing upcoming elections. The status of bilateral relations could strongly influence the course of events after an act of terror. Islamabad's efforts to distance itself from the attack would depend, in part, on prior steps taken to shut down militancy. As one Indian participant put it, "The trend will determine the response." In situations where trust is absent and communication channels are closed, the ability to control escalation would be reduced. During such periods of strained relations, declaratory statements lack credibility and will likely be insufficient. Verifiable actions would be required to defuse a crisis and improve relations. Once fighting begins, bilateral diplomacy between India and Pakistan would likely be quite limited, or cease altogether. Instead, diplomacy would likely be directed at third parties, multilateral, and international organizations. Third-party facilitation efforts, including verification of positive steps, could be essential for escalation control.

Mobilization of Forces

Mobilization is a step up on the escalation ladder. This step could be misinterpreted as it might be viewed as either a substitute for military action or as a prelude to it. However, the participants generally agreed that the intelligence services of both sides should be able to identify the last steps that come between mobilization and the initiation of conventional conflict. Thus, mobilization, by itself, need not lead to war.

If troops are already mobilized when a triggering event takes place, decision makers have limited room to avoid escalation, assuming that they wish to do so. Similarly, if troops had been recently mobilized (and subsequently demobilized) when a triggering event occurs, policy makers might feel that re-mobilization without the use force would not be a preferable option.

Full-scale mobilization of land forces is not necessary to carry out limited attacks. Operations at the brigade level could be used to strike targets across the LoC or the International Border (IB), or to capture posts along the LoC. Air strikes and/or helicopter-borne commando raids could be used to attack targets related to infiltration. Participants generally agreed that the repercussions of limited attacks would be far greater if carried out in the context of twin mobilizations. Even in the absence of mobilization, the repercussions of limited attacks might be difficult to anticipate.

Escalatory Responses

Participants generally agreed that attacks across the LoC by fixed-wing aircraft would be viewed as more escalatory than the use of helicopter gunships, and that attacks across the IB would be inherently more escalatory than attacks across the LoC. There was also general agreement that the use of ballistic missiles in warfare would be more escalatory than the use of combat aircraft. Many assumed that the use of one escalatory instrument—say combat aircraft—would then set a baseline for the next military engagement. As doctrine evolves and forces become more integrated, air power is likely to become more of a factor in escalation scenarios. The positioning and use of airpower are not well-developed signaling devices, but the participants generally acknowledged airpower's inherent escalatory potential, not just in terms of the targets struck, but also if there are high-levels of attrition in air combat.

Participants generally acknowledged that limited, punitive strikes across the LoC would likely be viewed as escalatory, warranting a response. However, there was no general agreement as to whether the dangers of escalation might be limited. It was unclear to participants how a series of punitive strikes (attack, response, counter-response, etc.) would end, since neither side would be willing to concede ground in this cycle. At the same time, it was generally recognized that escalation control required a relationship between target and grievance. Limited strikes must have limited objectives. The participants agreed that total war and total victory are not options in South Asia.

Scenario 2: Conventional War To A Nuclear Exchange

Accidental Detonation

Participants were asked to consider, during the course of a limited conventional conflict, what would happen if there were an explosion that released radiation. The cause of a release of radiation might not be clear in the fog of war. It might be the work of a terrorist group, either in the form of a "dirty bomb" or even a low yield nuclear detonation. It might be the result of an air strike against a location that was not presumed to be a nuclear target. It might be the result of a transportation or weapon-handling accident. It could also be an act of sabotage.

In the event of a release of radiation, participants considered the questions needed to be asked and the information required by decision makers, including: What happened? Why did this happen? Was it accidental or purposeful? Where are our assets? Could it be one of ours? Is it one of theirs? Where exactly did this happen? Was it at a location in which military operations have been undertaken? How large was the explosion? What was the damage? What impact will this have on our military plans and operations? What is the situation on the battlefield? Are red lines being approached? How should we respond?

Participants were aware of the difficulties of ascertaining reliable and accurate information under these circumstances. Indeed, the difficulty of obtaining accurate and timely information—such as whether a detonation might have been caused by a conventional attack, or by accident, sabotage, or the failure of safety mechanisms under great duress—during a period of time when there would be rampant press speculation and public outcry was acknowledged. An exceptionally large explosion—perhaps caused by the destruction of an ammunition dump—could also generate rampant speculation. Some participants expressed skepticism that a detonation could be carried out by a terrorist group.

Response Options

Accurate intelligence on the location and status of nuclear assets would be critical information for national leaders during crisis and wartime. Intelligence assessments might be sub par in the "fog of war," and could hamper decision-making. American intelligence-gathering capabilities might be of help in identifying the location and other aspects related to the nuclear event, but attributing the source of the material used could be difficult and would take time, in any event. The international community would certainly become energized but the victimized side might not seek diagnostic help in determining who was responsible for a hard-to-attribute event. Some participants believed that efforts would be made to pause, take stock of the situation, send an investigative team, and discuss all of the possible options. Others, however, questioned whether such an orderly response would occur. Heavy media coverage, extremely powerful domestic political constraints, and public outcry could hasten the decision-making process.

Complications

Participants concluded that it would be difficult, but still possible, to control escalation in the event of a nuclear accident in wartime that does not produce a mushroom cloud. They also concluded that it would be extremely difficult to control escalation in the event of the appearance of a mushroom cloud, for whatever reason. There would be a strong predisposition to believe that a detonation would be intentional rather than accidental, and that subsequent detonations would likely follow. There would be very little trust in Pakistan in India's no first use pledge. Even if the attack were an accident, there would be concerns that retaliatory strikes could be forthcoming, raising pressures of preemption.

Reliable lines of communication would be essential in such dire circumstances, but trust in the messages received would be an issue. Professions of innocence might not be believable. At the same time, the absence of communication from the side suspected of deliberate use of a weapon would likely be viewed as confirmation. Another possibility is that lines of communication could be hard to use if the detonation took place in places where leaders reside.

The participants concluded that the threat of acquisition by terrorists of highly enriched uranium and their ability to build a nuclear weapon might not be properly appreciated. In this scenario, participants believed that nuclear terrorism would probably occur away from the battlefield, most likely in a city. If a city suffered a terrorist nuclear attack, the potential for escalation would be very high.

Participants also discussed the role of air power in scenarios of a limited conventional war, and in the event of a crossing of the nuclear threshold. Some participants concluded that, during a conventional conflict, the air forces of the two sides could be expected to attack each other's air bases and related targets, acknowledging that this would raise questions of escalation control. The question of target avoidance was raised, but the difficulties of this in wartime were also acknowledged.

Escalation Control Measures

The final afternoon plenary session was devoted to a discussion of possible escalation control measures. Each participant was asked to offer one proposal for escalation control. Additional ideas were solicited once everyone had spoken. The proposals can be grouped into five broad categories:

1) Improving bilateral relations

- Initiating bilateral dialogue
- Establishing a solid bilateral relationship before a crisis occurs
- Sharing knowledge of decision-making processes
- Increasing transparency in nuclear doctrine and capabilities
- Developing a common vocabulary regarding doctrines and red lines
- Avoiding conventional war
- Establishing a quiet LoC
- Increasing public awareness of nuclear dangers

2) Nuclear risk reduction and strategic restraint

- Negotiating verifiable agreements on nuclear restraint
- Negotiating an agreement not to launch missiles during periods of crisis
- Ceasing bellicose nuclear rhetoric
- Agreeing not to develop or deploy tactical nuclear weapons
- Negotiating intrusive treaties relating to nuclear capabilities
- Avoiding new, destabilizing, nuclear developments
- Giving consideration to provisions found in the Prevention of Dangerous Military Activities Agreement between the United States and the Soviet Union
- Establishing nuclear risk reduction centers

- Establishing symmetry in nuclear doctrines
- Mutually declaring, akin to the Reagan-Gorbachev statement, that a nuclear war could not be won and must never be fought
- Avoiding sensitive targets in the event of a conventional war—especially airfields
- Refraining from giving pre-delegation of authority to use nuclear weapons
- Conducting similar, scenario-based discussions on the possible use of chemical or biological weapons

3) Safety and security measures

- Establishing improved and comprehensive safety and security norms in both countries
- Strengthening personnel reliability programs and systems
- Conducting nuclear safety and security audits by units that might "check the checkers"
- Enlisting third-party facilitation on nuclear security
- Stronger understanding by national leaders of their own nuclear capabilities and procedures
- Greater public awareness of nuclear dangers

4) Improving intelligence

- Acquiring technology to help provide prompt and accurate information concerning missile launches and nuclear detonations
- Refining forensic and diagnostic tools for determining the source and circumstances surrounding nuclear accidents
- Greater utilization of commercial satellite imagery to prevent surprises

5) Communication

- Hardening communication channels
- Establishing nuclear risk reduction centers in both countries
- Establishing a multi-nodal and multi-level structure of bilateral communication, including a hotline between the employment control committee in Pakistan and its functional equivalent in India
- Upgrading the existing DGMO hotline
- Establishing a dedicated hotline between the air force chiefs
- Keeping lines of communication active. When they become inactive, it is harder to make proper use of them in a crisis. Hotlines have sometimes been used multiple times daily in previous crises

- Hotlines could have greater utility if they had conference calling capabilities

The participants agreed that the Lahore Memorandum of Understanding (MoU) provides a very relevant work program on which to reduce nuclear risk. Additional measures could be added to the MoU, but rather than to seek a negotiated amendment, it should be implemented first and then built upon.

Participants: India: Shankar Bajpai, Salman Haidar; V.P. Malik; S.K. Mehra; M.K. Narayanan; V.R. Raghavan. Pakistan: Qazi Javed Ahmed; Zafar Cheema; Mahmud Durrani; Jehangir Karamat; Farrakh Khan; Najmuddin Shaikh; Shaharyar Khan; United States: Michael Krepon, Peter Lavoy; Joan Rohlfing; Scott Sagan.

Second Stimson Center Workshop On Escalation Control
20-23 May 2003

Introduction

Sixteen Indian, Pakistani and US participants met at the Bear hotel and conference facility in Woodstock (UK), from 20-23 May 2003 to discuss escalation control in South Asia. This workshop was convened in an entirely different, and far more positive, atmosphere than our first gathering, when relations between India and Pakistan were in a deep freeze. This time, we convened after the announcement in Srinagar on 18 April 2003 by Prime Minister A.B. Vajpayee to offer "a hand of friendship" to Pakistan. Consequently, our deliberations focused not only on escalation control measures, but also on ways to make the most of this hopeful development.

Process

Participants agreed that it was imperative to establish a process of dialogue that would be able to withstand attempts at disruption. Success on the toughest issues were unlikely to come quickly, and major breakthroughs were not anticipated. As discussed in the first workshop, participants stressed that the political context in which acts of terror occur would determine how disruptive they would be. It was therefore essential to create a positive political context for dialogue by taking many achievable steps. At the same time, substantive discussions were needed on Kashmir. Real engagement could be undertaken without withdrawing from principled positions. The establishment of a back channel between national leaders, in which specific concerns and ameliorative steps could be communicated, would be essential to counter acts of terror designed to stop this process. They agreed that private communications were likely to produce better results than rhetorical exchanges.

Escalation Control Measures

Participants were asked to assess the accuracy and completeness of the summary of our first workshop. Participants agreed that the summary was accurate and useful, and that it ought to be circulated privately to key audiences before its public release. The following additional points were made:

- One important area that we did not discuss was the role that intelligence assessments and misestimates play in escalation control and during crises.
- Nor did we discuss the use of chemical and biological weapons, especially in light of the formalized Indian nuclear doctrine.
- Escalation control issues relating to nuclear-capable forces need to be addressed on a priority basis. However, there were very few experts in the two foreign ministries with the background and experience to address the many measures we had considered.

At our first workshops, participants were asked to list specific measures that could be useful for escalation control. This time, participants were asked to "vote" for the three most useful and "doable" measures. The voting was as follows:

Measures to prevent dangerous military activities: (*11)*

- negotiating a nuclear restraint regime
- avoiding missile launches in crisis
- avoiding sensitive targets
- quieting the LoC

Measures to improve communication: *(10*)

- establishing nuclear risk reduction centers
- establishing multi-nodal, multilevel communication system
- establishing back-channel communications

Declaratory measures: *(10)*

- agreeing on definitions on nuclear-related issues
- increasing transparency in doctrine
- declaring that nuclear war cannot be won and must never be fought
- decreasing bellicose rhetoric
- increasing public awareness of nuclear dangers

Measures to avoid new destabilizing nuclear developments: *(8)*

- agreeing not to develop or deploy tactical nuclear weapons

Measures to stabilize nuclear deterrence: *(4)*

- developing a stable, second-strike nuclear capability
- establishing effective command and control
- refraining from pre-delegation
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Measures to improve nuclear safety and security: *(4)*

Nuclear Terrorism

Our first workshop elicited a collaborative discussion on escalation control by means of scenarios involving the detonation of a "dirty bomb," the detonation of a low-yield nuclear device by a terrorist group, and the accidental or inadvertent detonation of an Indian or Pakistani nuclear weapon. Some participants expressed skepticism about these scenarios, and this discussion raised a number of questions that US participants were unable to answer in detail. A briefing by Kishore Kuchibhotla and Joan Rohlfing allowed the participants to address these topics in greater depth.

Dirty Bombs

The briefing demonstrated that the area contaminated by a dirty bomb attack could be very expansive. Even the equivalent of two paperclips worth of certain radioactive substances could, if used effectively, impair the heart of major cities for many years, with immense psychological and economic impacts. Radiation sources for such an attack abound throughout the world and in South Asia. In this scenario, experts worry most about the "insider" threat—individuals working at facilities where these materials reside.

Low-Yield Nuclear Weapons

With many recorded incidents of stolen highly enriched uranium (HEU), and with difficulties in securing existing stockpiles, terrorist groups could gain access to bomb-making material sufficient to create a nuclear device. A single mushroom cloud would have immense and long-lasting impacts. Accidental detonation could occur as a result of a weapons-handling accident or a conventional attack against a nuclear warhead or storage area. A conventional explosion could result in a fractional or full nuclear yield, depending on the safety features employed. Even with elaborate safety mechanisms, an explosion with no nuclear yield could disperse highly radioactive material in the surrounding area. The electromagnetic pulse effects of even a low-yield device could seriously damage civilian infrastructure. Nuclear forensics after a detonation could employ a host of techniques to determine location, yield, weapon type, and design. Attribution of the source of the device could prove difficult, however, as the country of origin for the nuclear material would be unlikely to acknowledge its loss.

Some doubt was expressed about the likelihood of nuclear terrorism in South Asia, but most participants acknowledged a greater appreciation of this threat. There was general agreement on the need for increased security of nuclear materials used for civilian as well as military purposes. Participants asked the Stimson Center to refine the briefing for subsequent distribution.

Nuclear Doctrine, Rhetoric, and Signaling

After our first workshop, participants expressed an interest in delving more deeply into questions relating to nuclear doctrine, rhetoric, and signaling. To help provide depth in this area, Zafar Cheema, Rahul Roy-Chaudhury, and Peter Lavoy made presentations on nuclear message sending. Each presenter was asked about the intended audiences for messages (domestic, cross-border, US/West), and whether consistent and clear messages could be conveyed in light of the need to address all three audiences. How was the intended message heard? Have there been miscommunications between the message sender and the intended receiver? What can governments do to clarify deterrent messages in a stabilizing way? Is this possible?

Professor Cheema noted that Pakistan has formulated a nuclear doctrine that has yet to be published and may not be published. It consists of three basic components: nuclear posture, contingencies for employment of nuclear weapons, and command and control. The nuclear posture is one of minimum credible deterrence and adequate conventional defense. The nuclear capability must be credible and available when the country needs it. Authoritative Pakistani spokespersons have spelled out general guidelines for use in situations including: if India attacks Pakistan and controls large parts of Pakistan; if India strangulates Pakistan economically, and perhaps if India pushes Pakistan into political destabilization or facilitates large-scale internal subversion.

Professor Cheema noted that an Indian audience might view such expositions as overdrawn, or as an attempt by Pakistan to "bargain" the nuclear threshold. The rejoinder is that within each of these nuclear contingency categories there is a threshold for use that must remain ambiguous. Pakistan rejects a no first use (NFU) doctrine because it would be non-binding, and because it would compromise Pakistan's nuclear deterrent. Besides, neither side would lend much credence to such a pledge. To maintain flexibility in nuclear posturing and to address Pakistani concerns vis-à-vis the conventional military balance, the threat of escalation to the nuclear option is necessary.

Participants concluded that bellicose nuclear rhetoric was unwise and suggested that there was a lack of responsible nuclear stewardship. They agreed that government officials would be wise not to speak extemporaneously on the subject, and that official comments, particularly during crises, should be restricted to the top-most leaders.

Mr. Roy-Chaudhury's analysis of the 2001-02 crisis concluded that nuclear rhetoric by India was consciously minimized because New Delhi did not wish to lend credence to the Pakistani claim that Kashmir was a nuclear flashpoint. There were, however, some extemporaneous statements on nuclear matters that were inconsistent and were quickly clarified. New Delhi sought to counter Pakistan's nuclear rhetoric by claiming that its neighbor was reverting to irresponsible "antics" and attempted nuclear "blackmail" and "nuclear terrorism." After the crisis was over, New Delhi's nuclear rhetoric changed, perhaps to affirm that it would not be dissuaded from military action in the future, if the need arose.

Participants generally agreed that nuclear signaling during crises was not clear, in part because of the multiple audiences that national leaders wished to reach. There was also a natural tension between the need to signal deterrence and the need to affirm responsible nuclear stewardship. Many participants felt that we could be reading far too much into the messages sent, and that extemporaneous messages—say, in response to a question asked by a reporter—should not be viewed as reflecting a carefully considered national strategy.

Mr. Lavoy's presentation raised the dilemma that nuclear signaling could be viewed both as enhancing deterrence and raising the risk of escalation. In his view, the advent of nuclear weapons in South Asia has meant that crises have become a substitute for war, with both sides seeking to achieve victory in crisis. Victory, in turn, requires new ways to make threats credible, including the threat that nuclear weapons might be employed. This dynamic makes escalation control more necessary, but also more difficult, since stabilizing measures would necessarily restrain the ability to signal resolve. Stabilizing measures might therefore be sacrificed during a crisis.

Participants also considered signaling by the United States during a crisis, and whether US signals were properly read by South Asian audiences. An important signal during the 2001-2002 crisis was the evacuation of American and British nationals. Was this a manipulative attempt to leverage India and Pakistan, or a true reflection of US concerns that a war might be imminent? Both conclusions could be reached.

Participants generally agreed that nuclear signaling at this early stage was a murky and imperfectly understood practice on the subcontinent. Greater clarity could come with more discipline (and fewer spokespersons) conveying messages.

Missiles and Escalation Control

Another topic from the first workshop that participants desired to explore in greater depth was the issue of missiles and escalation control. Feroz Khan made a presentation on this subject, followed by a response from Raja Menon and general discussion.

Brigadier Khan's presentation concluded that missiles could be destabilizing because of their short time of flight, their inability to be recalled, the ambiguity of their payloads, and the difficulty of distinguishing between defensive moves and offensive preparations for launch. He noted that ballistic missile flight tests during crises are a recent phenomenon. Flight tests during crises could be conducted to validate technical designs; to demonstrate the credibility of the deterrent; to convey messages to domestic audiences; or to prompt outside intervention. In his view, missile flight tests are unlikely to impress the national command authority of the opposing country.

In Brigadier Khan's view, signaling deterrence through missile flight-testing might have run its course in South Asia. Participants disagreed on this point. Some worried that India and

Pakistan might be "running out of options" short of force to signal credibility. Others felt that there was still signaling room available, such as testing more than one missile at once. There was discussion about the possibility of using a conventionally armed ballistic missile as a "signal" of resolve during warfare.

Participants generally agreed that the movement of missiles during a crisis was more of a concern than flight-testing. Reports of the Kargil crisis suggest that varying interpretations could be given to the movement of missiles. Some argued, while others questioned, that Washington would be more likely to have a better understanding of "ground truth" than the side being signaled through the movement of missiles. There was general agreement that missile moves in a crisis contribute to escalation, in part because of uncertainties associated with missile moves. It was unclear from prior crises, for example, whether missiles were mated with warheads during crises. Worst-case assumptions might not be true. Most, but not all, participants concluded that the risks exceeded the benefits of mating of warheads with missiles before or during a crisis.

Recommendations

The third day of the Stimson Center's escalation control workshop focused on a commonly agreed work agenda to reduce nuclear danger. Participants agreed to focus on practicable as well as desirable measures that could be implemented as soon as possible. The following agenda items were agreed upon:

Establishment of National Risk Reduction Centers

Separate centers could be established in India and Pakistan in order to: (a) serve as a focal point for the administration of CBMs that require notifications; (b) help revive existing CBMs; (c) provide a mechanism for notifications for new CBMs, such as notifications of nuclear accidents or incidents and missile notifications (see below); (d) provide a channel of communication that would be utilized regardless of the state of bilateral relations.

Because some notifications are non-nuclear related, participants felt that the term "national risk reduction" worked better than "nuclear risk reduction." Participants concluded that risk reduction centers should be supplemented with dedicated "hotlines" and periodic consultative meetings regarding the implementation of agreed measures.

Participants discussed whether the centers should be freestanding, or attached to an existing operation. Possible locations for the centers were discussed, including the Integrated Defense Staff and the National Security Council Secretariat in India, and the National Military Operations Center in Pakistan. Participants agreed that detailed studies would be needed on these topics, as well as on the issue of whether the centers should be manned continuously.

Missile-related Measures

Participants agreed that four specific measures to reduce dangers associated with missile launches and movements during crises were both practicable and desirable: (a) formalizing and properly implementing the agreement concerning prior notification of missile launches, and formalizing the time line for such notifications; (b) agreeing not to flight test missiles in the direction of the other country; (c) agreeing to flight test missiles only from designated test ranges; and (d) providing advance notification of the movement of missiles for training purposes.

Participants also discussed the feasibility of agreements relating to the movement of missiles in conjunction with large-scale exercises, during crises, and during peacetime, but identified several obstacles to such agreements, including verification and reaching a common definition of what constituted a "crisis." Participants agreed that it was impractical to ban missile movements and flight tests in periods of tension, but that the accords listed above could serve to minimize misunderstandings and the potential of inadvertent escalation.

While noting verification and other difficulties involved, some participants raised the notion that the purposes of escalation control and regional stability would be served by having only conventionally-armed short-range ballistic missiles and, indeed, to eliminate these missiles over time, in light of their extremely limited military utility.

Participants also decided that agreed measures related to missiles might be accompanied by a "chapeau" expressing the reasoning of national leaders behind according a high priority to such CBMs. This chapeau might include the reason, as discussed in our workshop, of the difficulty in distinguishing between missile movements carried out for defensive purposes and preparations for offensive strikes.

Clarifying Terminology

Participants agreed that a greater mutual understanding of terms used by India and Pakistan on nuclear-related programs, deployment and doctrine—or, where possible, common terminology—could reduce misunderstanding and increase crisis stability. They suggested that the Stimson Center might facilitate this undertaking by surveying the terminology now employed and interviewing officials about intended meanings. Government and military officials could then meet to discuss terms and definitions with a view toward the joint or separate publication of a glossary.

Leadership Declarations Affirming Responsible Nuclear Stewardship

Participants agreed that joint statements at the highest level could help defuse nuclear dangers and facilitate an improvement in bilateral relations. In South Asia, such a statement might not replicate the Reagan-Gorbachev declaration that a nuclear war could not be won and must not be fought. Instead, it might focus on the obligation of national leaders to (a) decrease or to end bellicose nuclear rhetoric; (b) negotiate and properly implement measures to reduce nuclear dangers, whether bilateral or unilateral; (c) implement improved safety and security measures; and (d) refrain from deploying “tactical” nuclear weapons.

Increasing Awareness of Nuclear Dangers

Participants agreed that greater awareness of nuclear dangers, particularly with regard to the possible acquisition of nuclear materials by terrorist groups, would be advisable. Toward this end, participants asked the Stimson Center to further refine the workshop presentation on nuclear terrorism for selected private and subsequently public distribution.

Work Agenda

Workshop participants suggested several topics for subsequent deliberation and for the Stimson Center to investigate. These topics included:

1. The impact of new military technologies (including ballistic missile defense) on strategic stability in southern Asia
2. Intelligence, misperception and escalation control
3. Tactical nuclear weapons: Definitions and verification
4. A glossary of definitions of nuclear-related issues
5. Measures to improve command, control, and communication
6. Preparation of materials for increased awareness of nuclear dangers
7. Preparation of a compendium of existing proposals relating to Kashmir and fresh thinking on this topic

Participants: India: Rahul Roy-Chaudhury, Salman Haidar, V.P. Malik, S.K. Mehra, K. Raja Menon, M.K. Narayanan, V.R. Raghavan. Pakistan: Zafar Cheema, Jehangir Karamat, Feroz Khan, Shaharyar Khan, Najmuddin Shaikh, Saeed Uz Zafar. United States: Michael Krepon, Peter Lavoy, Joan Rohlfing.

Nuclear Terrorism and Nuclear Accidents in South Asia

*Kishore Kuchibhotla and Matthew McKinzie**

Introduction

With the arrest of alleged Al-Qaeda terrorist Jose Padilla at Chicago's O'Hare Airport on June 10, 2002, the concept of a "dirty bomb" or a radiological dispersal device (RDD) entered the consciousness of the American public. The US Attorney General John Ashcroft sensationally reported that such a weapon "spreads radioactive material that is highly toxic to humans and can cause mass death and injury."[1] Months earlier, on March 6, 2002, the Senate Foreign Relations Committee held hearings on the potential for acts of terrorism involving radioactive materials. Here there was agreement among experts within and outside the US government that a dirty bomb would not cause large loss of life—as in the September 11th, 2001 terrorist attacks—but instead incite widespread panic and massive economic damage.[2]

One nuclear expert testifying before the Senate committee described a scenario in which low levels of radiation are quietly spread around a city.[3] An anonymous tip alerts the police, who confirm the attack with radiation detectors. While no one in the contaminated area would die or even get ill as a result of short-term exposure to the radiation, evacuation and cleanup of part of the city would be required. Exposure to such low levels of radioactive material over many years would cause an increased risk of cancer. Potentially whole buildings would have to be torn down and disposed of as radioactive waste, and the heart of the city might be abandoned for years and rehabilitated only at great expense.

Nevertheless, accidents involving the dispersal of radioactive material have occurred that are similar in some ways to an RDD attack -- most notably in Goiania, Brazil in 1987-1988.[4] The records of these events suggest that, depending on the type and amount of radioactive material involved in an RDD attack, tens or hundreds could die and potentially thousands grow ill from radiation poisoning.[5] Furthermore the US Department of Homeland Security believes that the

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[1] "Ashcroft Statement On 'Dirty Bomb' Suspect," CNN.com (June 10, 2002), available online at http://www.cnn.com/2002/US/06/10/ashcroft.announcement/.

[2] "The Terrorist Nuclear Threat, Focusing on Dirty Bombs and Basement Nukes," Hearing of the Senate Foreign Relations Committee (March 6, 2002).

[3] Dr. Steven E. Koonin, "Radiological Terrorism," Prepared Statement before the Senate Foreign Relations Committee (March 6, 2002).

[4] "The Radiological Accident in Goiania," International Atomic Energy Agency (Vienna: 1988), available online at http://www-pub.iaea.org/MTCD/publications/PDF/Pub0815_web.pdf.

[5] Peter D. Zimmerman with Cheryl Loeb, "Dirty Bombs: The Threat Revisited," *Defense Horizons* no. 38 (January 2004), p.1.

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threat of RDD attacks against the United States is not only credible, but also a near-term threat. On New Year's Eve, 2003, nuclear experts mingled with holiday crowds in major cities with radiation detectors hidden in briefcases and golf bags during the elevated terrorist alert level "Code Orange."[6]

The threat of nuclear, or radiological, terrorism is not limited to the confines of the United States. South Asia continues to be a volatile region that hosts many militant groups and sources of radioactive material. Because of these and other factors, nuclear and radiological terrorism remains a frightening possibility in India and Pakistan. The source material for nuclear terrorism could come from illicit transactions of poorly protected materials originating outside the region, as well as material from within the region used for military or civilian purposes. India and Pakistan have established regulatory bodies and agencies to deal with the safety and security of their nuclear materials, but they may not protect against every potential threat.

The possibility of a deliberate nuclear exchange between India and Pakistan has receded with the efforts by Prime Minister Atal Bihari Vajpayee and President Pervez Musharraf to engineer improved relations. Nevertheless, three other types of events could prompt unintended escalation in South Asia. These scenarios are a terrorist use of RDDs; a terrorist detonation of a nuclear weapon; and the accidental explosion of nuclear arms—for example at military bases in either India or Pakistan. These three events, none of which involve the deliberate use of nuclear assets by India or Pakistan, could have horrific consequences ranging from the significant loss of life and long-lasting contamination to a crossing of the nuclear threshold -- especially if the event occurred during a crisis.

Nuclear weapons were used to devastating effect to end World War II and thankfully none have been detonated in warfare or fired in anger since 1945. But many accidents have occurred involving military and non-military nuclear programs. There is now growing awareness among public officials about the need to increase security at military and civilian facilities where dangerous materials are located. While the highest security levels are associated with nuclear weapons and their infrastructure, radioactive materials can also be found at many research laboratories and hospitals. All national leaders, including the leaders of India and Pakistan, have a grave responsibility to maintain responsible stewardship over nuclear materials. However carefully South Asian leaders work to avoid crossing the nuclear threshold, accidents can happen. Moreover, terrorist groups in India and Pakistan, as elsewhere, might seek to produce casualties or massive disruption by means of radioactive materials.

Methodology

We have calculated the consequences of nuclear events with the computer code HPAC (Hazard Prediction Assessment Capability), which is now widely used in the US government for

[6] John Mintz and Susan Schmidt, "'Dirty Bomb' Was Major New Year's Worry," *Washington Post* (January 7, 2004), p. A1.

emergency planning and military analysis. HPAC is an unclassified collection of computer models and databases produced by Science Applications International Corporation for the US Defense Threat Reduction Agency (DTRA), an agency of the US Department of Defense. In its documentation HPAC is described as:

> a forward deployable, counterproliferation and counterforce tool for weapons of mass destruction (WMD). The HPAC software assists war fighters in weaponeering targets containing hazardous nuclear, biological and chemical (NBC) materials. HPAC also supports emergency responses to NBC accidents or terrorist incidents."[7]

HPAC calculates nuclear weapons effects and the movement of radioactive particles and biological or chemical agents through the atmosphere for scenarios such as nuclear explosions; nuclear facility accidents; RDD attacks; chemical or biological weapons use; and accidents or military strikes at biological weapons facilities.

Some of the incident models—for example the nuclear fallout model—have their origins many decades ago in Cold War research at the US national laboratories. These so-called "legacy" codes were updated in HPAC with improved atmospheric transport models.

Other software packages—such as Lawrence Livermore National Laboratory's HOTSPOT which is readily available on the Internet—did not provide as much flexibility in programming and analysis as HPAC. In particular, HPAC's ability to analyze accidental nuclear explosions based on the partial nuclear yield permitted a parametric study. Although HPAC offers a streamlined graphical user interface, it is important to note that it uses separate programs to investigate the three types of nuclear events reviewed here. While all three types of attacks disperse nuclear materials, they differ profoundly in their weapons effects. In addition, effects from the same class of weapons will further vary depending on such factors as weapon yield, design, prevailing weather conditions, and population density. The assumptions used in our calculations are noted for each case.

The exposure and contamination contours calculated with HPAC can then be mapped in an interface that includes population data to assess casualties. We have also used commercially acquired satellite imagery of Indian and Pakistani cities to provide a more detailed assessment of the consequences of these scenarios.

For these calculations, we have arbitrarily chosen historical weather conditions for the month of May. Seven cities—Lahore, Karachi, and Islamabad in Pakistan, and Mumbai, New Delhi, Bangalore, and Madras in India—were considered in this study.

Radiological Terrorism

Radiological terrorism—the terrorist use of a dirty bomb—poses a substantial threat to regional, national, and international security partially because of the relative abundance of

[7] Hazard Prediction and Assessment Capability (HPAC), Version 3.2.1 (July 12, 2000).

radioactive sources. Unlike the fissile material used to produce nuclear weapons that is stored in comparatively few locations, radiological materials are widely used in medicine and industry. These radiological materials may not be well guarded and are susceptible to theft from individuals who work inside, or outside, the facility.[8] Security regulations associated with these materials vary greatly among countries and even within a single country.

Radiological dispersal devices are not nuclear weapons, nor do they produce similar weapons effects. There is no nuclear yield and the amount of destruction and damage caused by an RDD are many orders of magnitude less when compared to a nuclear detonation. The greatest threats posed by an RDD lie in its capacity to wreak psychological and economic havoc on a city, as well as its potential to produce escalation. The "man on the street" might not dwell on the distinctions between a radiological weapon and a nuclear weapon, focusing instead on the fact that it is nuclear. The mass media might inflame public reaction and contribute to confusion, panic and pressure on national leaders to retaliate and escalate. Radiological contamination of any kind strikes fear into the surrounding community.

Radioactive materials can be categorized in terms of the strictness of controls governing their access and disposition. Material used for nuclear weapons and nuclear power plants are tightly regulated, making it difficult, but not impossible, to gain unauthorized access to these sites. Radioactive materials that have industrial and medicinal uses, ranging from the treatment of cancer to the sterilization of food and spices, typically are subject to minimal security, making them far more susceptible to unauthorized access and "insider" threats.[9]

Radioactive Material for RDDs

Some of the many types of radioactive material commonly used in industry and medicine have characteristics that would make them effective RDD weapons. Sealed radioactive sources—which are of particular concern—are produced in nuclear reactors as byproducts of nuclear fission or via target irradiation. For any particular radioactive material, knowing the type of ionizing radiation it emits is essential for protection, detection, storage, transport, and cleanup.

Ionizing radiation, which causes damage to human cells, comes in the form of alpha, beta and gamma radiation. These three types of radiation differ in their ability to penetrate materials. Alpha radiation can be blocked simply with a piece of paper; beta radiation requires only a thin piece of metal or glass for effective shielding; and gamma radiation requires thick lead or concrete. While shielding can protect individuals from radioactivity in their environment, internal damage will result if radioactive particles are inhaled or ingested.

Attributes of radioactive material that are particularly important with respect to RDDs are half-life and activity. The half-life of a material is defined as the length of time it will take for

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[8] Evelyn Mullen, Greg Van Tuyle, and Rob York, "Potential Radiological Dispersal Device (RDD) Threats and Associated Technology," LLNL.

[9] Ibid.

half of it to radioactively decay. An effective dirty bomb has a half-life that is neither too short nor too long:

> Radioactive sources with very short half-lives (hours or minutes or less) do not last long enough to give terrorists sufficient time to produce radiological weapons with those substances; nor do they exist long enough to contaminate places for an appreciable time. In contrast, those sources with very long half-lives (millions of more years) release radiation at much slower rates and typically would not be ideal for radiological weapons devised to maximize the output of radiation during a relatively short time period – the human timescale.[10]

The activity of a material corresponds to the number of radioactive disintegrations per second. A common unit of measure of activity is the Curie (Ci), which corresponds to 37 billion decays per second. Naturally occurring radioactivity in the food that we eat or the air that we breathe contains miniscule amounts of radioactive activity (on the order of 10-11 Curies). By contrast, radioactive sources with levels of radioactivity from tens of Curies to a few thousand Curies could cause massive contamination if used in an RDD.

The specific activity of a material is the activity per unit mass, which can be expressed in units of Curies per gram (Ci/g). Very dangerous levels of radioactivity require only a small amount of the substance for materials with a large specific activity. For example, merely nine grams of Cobalt-60—or the equivalent of two paper clips worth of material—can be used to make a dirty bomb that could cause mass disruption. Table 1 lists the radioisotopes that are generally viewed as the greatest security risks because of their innate properties and potential for dispersal. This essay will model the terrorist use of RDDs containing two gamma radiation sources Cobalt-60 (Co-60) and Cesium-137 (Cs-137).

Table 1: Radioactive materials which could be used in an RDD and their properties.

Radioactive Material	Half-life	Specific Activity (Ci/g)	Type of Ionizing Radiation
Cobalt-60 (Co-60)	5.3 years	1,100	Beta, High-energy Gamma
Cesium-137 (Cs-137)	30 years	88	Beta, High-energy Gamma
Iridium-192 (Ir-192)	74 days	450-1000	Beta, High-energy Gamma
Strontium-90 (Sr-90)	29 years	140	Beta, Low-energy Gamma
Americium-241 (Am-241)	433 years	3.4	Alpha, Low-energy Gamma
Californium-252 (Cf-252)	2.7 years	536	Alpha, Low-energy Gamma

Source: Charles Ferguson, Tahseen Kazi, Judith Perera, "Commercial Radioactive Sources: Surveying the Security Risks," Monterey Institute of International Studies (January 2003), p 16.

[10] "Commercial Radioactive Sources: Surveying the Security Risks," Monterey Institute of International Studies (January 2003), p. 3.

The human health effects produced by exposure to radiation are medically classified as either deterministic or stochastic. An example of a deterministic health effect is radiation sickness. Here the health effect can be directly related to the radiation exposure as cause and effect. An example of a stochastic health effect would be cancer. Currently in the United States approximately 2,000 out of 10,000 people will experience some form of cancer during their lives. Exposure to low levels of radiation over time will increase that risk, but in most cases individual cancers cannot be identified as the result of radiation exposure—only statistics will show that connection.

The unit of measure of human radiation exposure is Roentgen Equivalent Man, or REM. REM is a unit of measure of the effect of ionizing radiation on the human body. Humans typically receive 0.3 REM/year from natural sources of radioactivity and an additional 0.06 REM/year due to the lingering after-effects of atmospheric nuclear weapons tests for a total exposure of 0.36 REM/year.[11]

The radiation dose calculations shown below are displayed in terms of Total Effective Dose Equivalent (TEDE), which includes doses from radioactive material deposited on the ground, suspended in the air, and inhaled over a period of four days.[12] In the United States, the TEDE calculated for an accident scenario is often used to understand what protective action for the public is required by federal guidelines. The US Environmental Protection Agency (EPA) considers health effects possible for TEDE of fifty or above. A TEDE of one is the EPA's Protective Action Guide (PAG) limit. A calculated TEDE of ten or above would require evacuation under all circumstances from the contaminated area, whereas for a TEDE of one, taking shelter is recommended under hazardous environmental conditions.

According to the US National Radiological Protection Board, deterministic effects "generally arise shortly after exposure to a radiation dose, but only if this dose exceeds some threshold value. The severity of these effects, but not the probability of their occurrence, depends on the level of dose."[13] Possible effects include "damage to body tissues such as the red bone marrow, gastrointestinal tract, central nervous system, lung and skin; at very high doses, these effects may lead to death within a short period."[14] For exposure times less than one day, very high levels of acute radiation would be necessary for such short-term health effects. Deterministic health effects can occur for acute doses above ten to fifty REM. Above 150 REM, death from radiation sickness is possible, with about half of all exposed persons dying who receive a dose of 600 REM.

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[11] Nuclear Regulatory Commission, "How Does Radiation Effect the Public," (June 23, 2003), available online at http://www.nrc.gov/what-we-do/radiation/affect.html.

[12] Hazard Prediction and Assessment Capability (HPAC), Version 3.2.1 (July 12, 2000), Internal exposure is extrapolated to a 50-year committed effective dose equivalent (CEDE).

[13] National Radiological Protection Board, "What Effects Can Radiation Have on Health?" (2004), available online at http://www.nrpb.org/faq/epidemiology/epid2.htm.

[14] Ibid.

The EPA associates stochastic effects with "long-term, low-level (chronic) exposure to radiation…Increased levels of exposure make these health effects more likely to occur, but do not influence the type or severity of the effect."[15] Stochastic effects include increased incidence of cancer as well as the possibility of hereditary mutations seen in later generations.[16] Our calculations of deterministic effects will be demonstrated as short-term health effects, whereas stochastic effects will be described using analogies to increased incidence of cancer. See Table 2 for an assessment of the long-term cancer risks associated with varying levels of REM exposure.

Table 2: Radiation dose levels correlated to increase in cancer.[17]

Total Effective Dose Equivalent	Additional Cancer Deaths per 100,000 People
0.1 REM	5
1 REM	50
5 REM	250
50 REM	2,500
150 REM	7,500
450 REM	22,500
600 REM	30,000

Source: "Understanding Radiation: Health Effects," US Environmental Protection Agency, (2003).

The guidelines established by nuclear regulatory bodies are an important benchmark for understanding the level of contamination in a given area. Within the United States, there is considerable debate about the amount of permissible radiation. The NRC, the International Atomic Energy Agency (IAEA), as well as the Health Physics Society (a non-governmental body of radiation experts) have set a limit of 0.1 REM/yr, or an additional four cancer deaths for every 100,000 people exposed.

[15] US Environmental Protection Agency, "Understanding Radiation: Health Effects," (December 3, 2002), available online at http://www.epa.gov/radiation/understand/health_effects.htm#est_health_effects.

[16] National Radiological Protection Board, "What Effects Can Radiation Have on Health?" (2004), available online at http://www.nrpb.org/faq/epidemiology/epid2.htm.

[17] There is one caveat in correlating REM exposure to long-term cancer increase. To define the myriad guidelines relating to low-dose exposure, the EPA, the Nuclear Regulatory Commission (NRC) and other governing bodies in the United States often assume a Linear-no-Threshold (LNT) dose-response relationship. This hypothesis directly extrapolates to low doses from high-dose exposure data acquired from cancer incidence among survivors from the Nagasaki and Hiroshima bombings and assumes that any amount of radiation may pose some risk for causing cancer and hereditary effect, and that the risk increases with higher radiation exposures. Without suitable large-scale statistics on low-dose exposure, those supporting the LNT hypothesis argue that this method is the only valid methodology. Critics of this hypothesis argue that there is no credible evidence to show that low-dose exposure to radiation is harmful. Some have even argued that low doses of radiation may have positive health effects. These arguments are based on the idea that there is indeed a threshold at which radiation exposure becomes inconsequential. We note this argument without trying to resolve it. Because government bodies will define national decontamination and evacuation procedures, we use the most recent guidelines proposed by various US regulatory agencies as a framework for understanding weapons effects.

RDD Scenarios

What follows are scenarios of three dirty bomb detonations, two in Karachi, Pakistan and one in New Delhi, India. The radiation exposure contours and extent of contamination produce many short-term and long-term health effects. A dirty bomb exploded in the heart of a city could have dire psychological and economic consequences. Some mitigating factors include the size of the contaminated area, any evacuation procedures, and the levels of panic and public hysteria. Some lessons can be learned from a real-life radiological accident that occurred in Goiania, Brazil.

Goiania, Brazil Case Study

In Goiania, Brazil in 1987, scavengers rummaging through the remains of an abandoned health facility acquired a Cesium-137 source encased in a lead canister. This is a similar level of radioactivity to that used below in Scenario Three. The canister, filled with a "luminous blue powder" (Cs-137), found its way into the hands of children, friends, and family of the scavengers. Lacking any knowledge of the potential dangers of the powder, many came into contact with the sources, and several ingested it. Contamination continued throughout the small city until it was reported to the Brazilian government officials a week after the canister was opened.

This well-documented case can be used as a point of reference for public response to a radiological incident. The impacts of the radioactive contamination of Goiania were both short-term and long-term. The immediate impact was difficult but not unmanageable. Over 100,000 people were screened for radioactive contamination, over 100 people were contaminated, and four people died. The longer-term psychological and economic effects, however, devastated the city and its inhabitants. Due to public perceptions and misperceptions, tourism to the area was down forty percent and still has not fully recovered. Agricultural and textile prices decreased by fifty percent. Fear of contamination was high and most places in Brazil boycotted goods from Goiania.[18]

If terrorists dispersed radioactive materials in a major city, the psychological and economic impacts would undoubtedly be far worse. Public hysteria would overwhelm local authorities, the economic consequences would be long lasting, and the government agencies responsible for public safety would come under severe scrutiny. While a dirty bomb may not be a weapon of mass destruction, its disturbing consequences qualify it as a "weapon of mass disruption."

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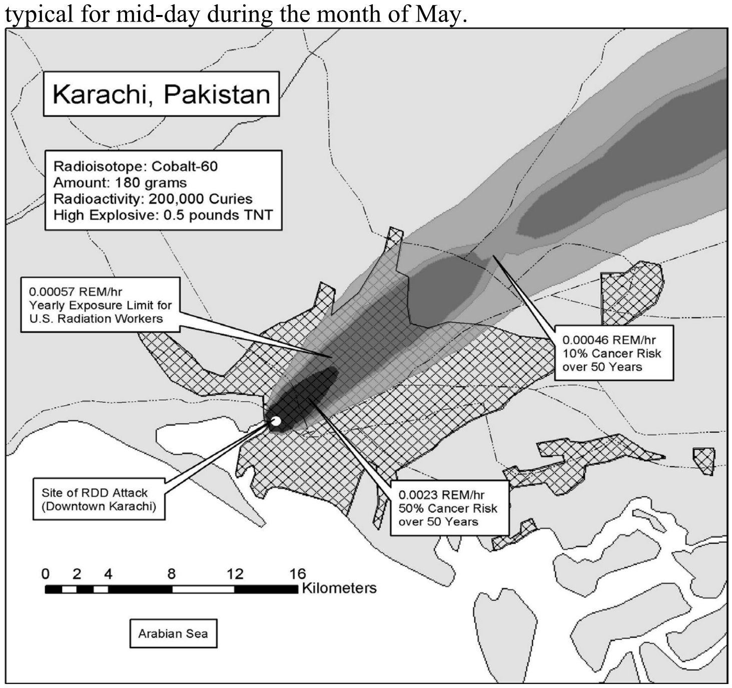
[18] Alex Niefert, "Case Study: Accidental Leakage of Cesium-137 in Goiania, Brazil, in 1987," *NBC-MED Online,* available online at http://www.nbcme.dorg/SiteContent/MedRef/OnlineRef/CaseStudies/csgoiania.html

RDD Scenario One: Karachi, Pakistan

Our first scenario looks at the use of a highly radioactive source: nearly 200 grams of Co-60 (200,000 Curies) in Karachi, Pakistan, dispersed using one-half pound of TNT. It is important to note that this amount of Co-60 would be extremely difficult to acquire, handle, and disperse. It would require the theft or seizure of an unusually large quantity of intensely radioactive material. Unless this Cobalt source was heavily shielded, anyone close to it would quickly die from the radiation exposure. Significant "insider" knowledge would be required for this theft and for successfully dispersing the material in an RDD attack. As such, we offer this scenario as a "worst case" analysis.

Figure 1a shows the extent to which the radiation plume extends over the city. The units plotted in Figure 1a are REM per hour (REM/hr)—the amount of radiation people would receive per hour or the dose rate. As can be seen from this figure, measurable radioactive contamination would spread over much of the city and well beyond it (fifty km or more beyond Karachi). The innermost, black part of the Cobalt plume that stretches about five kilometers from the attack site is the most contaminated zone. Here individuals would have a greater than 50 percent chance of contracting cancer as a result of living with this level of exposure for fifty years. The next-darkest part of the Cobalt plume shows the zone in which people would have a 10-50 percent chance of cancer over fifty years exposure, with the outermost part of this zone being the US exposure limit

Figure 1a: Overview of calculated Co-60 contamination in Karachi from a 200,000 Curie source dispersed by five pounds of TNT. Radiation dose units are TEDE (4-day exposure). Weather patterns are typical for mid-day during the month of May.

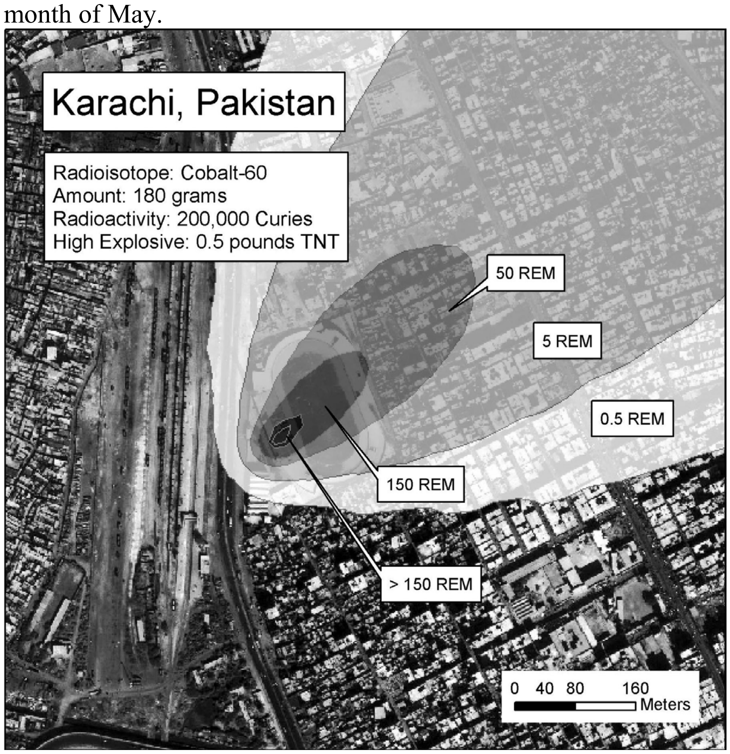


Source: Satellite Photo: Space Imaging

for radiation workers. The outermost part of the Cobalt plume—shown in lightest gray—is the public limit for exposure above background set in the United States. While no one would get immediately sick from these exposures, significant portions of Karachi would not be habitable unless the Cobalt was cleaned up at great expense.

The area in which people would initially suffer radiation sickness and potentially die would be close to the RDD attack site: up to about 250 meters away. This is shown in Figure 1b, which overlays the Cobalt plume on a high-resolution satellite image of Karachi. A stadium in downtown Karachi near the main railroad yard was chosen as the hypothetical attack site and serves as a reference scale for the innermost part of the Cobalt plume. If the stadium had been filled, most of the individuals inside and nearby would receive very high doses from the RDD attack. Survivors could carry radioactive contamination back to their homes and contaminate their neighbors and families.

Figure 1b: Close-up of calculated Co-60 contamination in Karachi from a 200,000 Curie source. Units are TEDE (4-day exposure). Weather patterns are typical for mid-day during the month of May.



Source: Satellite Photo: Space Imaging

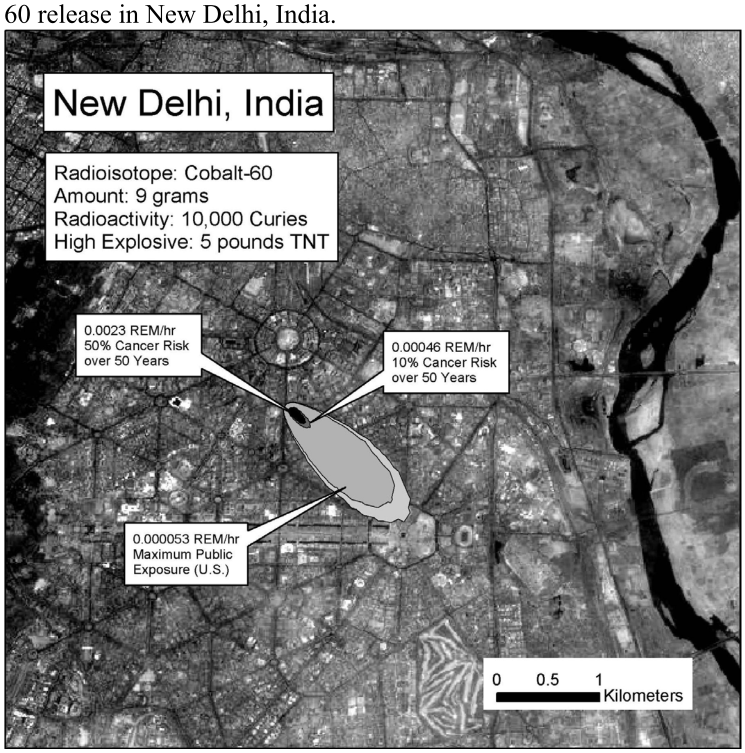
An RDD attack on Karachi with such a large source would be a national catastrophe. In an inner zone several hundreds of meters from the attack site people would succumb to radiation sickness. Survivors could spread intense radioactive contamination further. There would ensue a massive exodus of people from Karachi into neighboring towns and cities. Much of Karachi would be contaminated from the Cobalt plume to levels requiring cleanup and the destruction and disposal of building structures. Because of Karachi's strategic location as the key port of entry for Pakistan, this RDD attack would have massive ramifications for Pakistan's economic security.

RDD Scenario Two: New Delhi, India

The second scenario is more plausible than the previous one because of the smaller radioactive source involved: nine grams (10,000 Curies) of Co-60 dispersed by five pounds of TNT. This type and size of source can be stolen from a single cancer teletherapy unit. It can also be acquired by stealing a small percentage of material from a large industrial source. Such a source requires about nine grams, the weight of two paper clips, of Co-60.

As one can see from Figure 2, the extent of the radioactive contamination is far less than for the previous scenario, that used twenty times as much Cobalt in the hypothetical RDD. Any immediate deaths in this scenario would likely occur very close to the RDD attack site and would result from the bomb blast rather than the radiation.

Figure 2: Close up view of radiation contamination levels after Co-60 release in New Delhi, India.



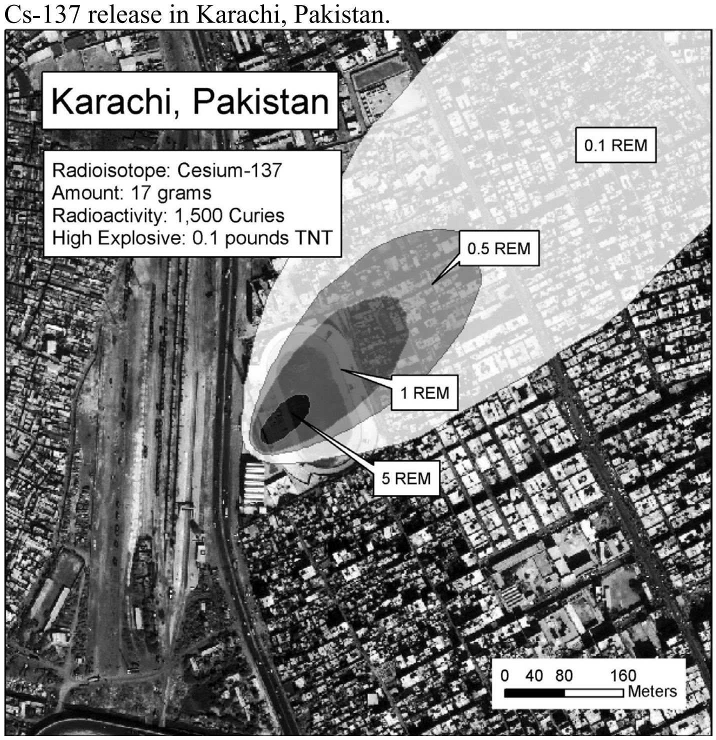
Source: Satellite Photo: Space Imaging

An area of about two square kilometers, or about thirty-three city blocks, would be contaminated to a level that would likely require cleanup. This could include, depending upon winds and the location of the detonation, Connaught place, India gate, and/or South and North Block. This can have serious impacts on New Delhi and India's economic health. Moreover, due to the bomb's location near the political heart of India, the possible impact on governance cannot be understated.

RDD Scenario Three: Karachi, Pakistan

This scenario simulates the use of a different radioactive source—seventeen grams (1,500 Curies) of Cs-137—which comes in the form of a powder and readily lends itself to dispersal by means of conventional explosives. This cesium bomb would have myriad long-term implications (Figure 3).

Figure 3: Close up view of radiation contamination levels after Cs-137 release in Karachi, Pakistan.



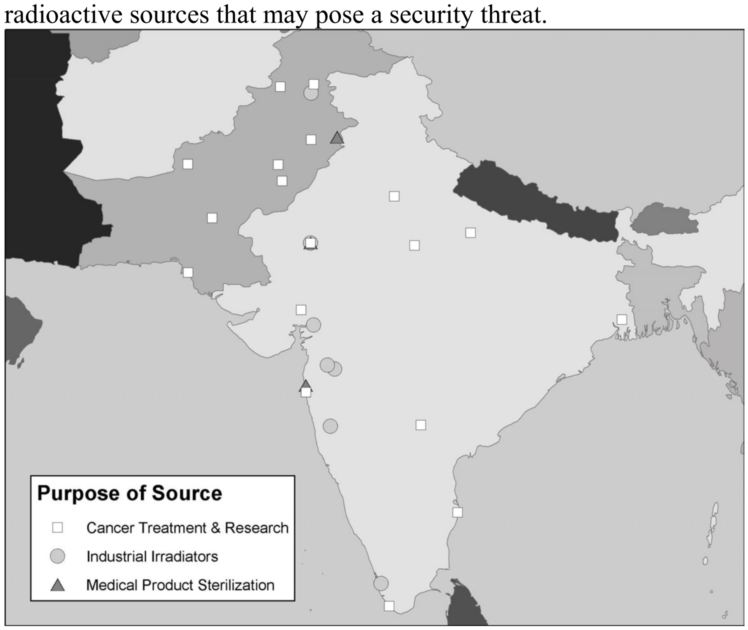
Source: Satellite Photo: Space Imaging

In the short term, there would be few deaths. The area contaminated would be approximately one square kilometer, or about five city blocks. The psychological and economic effects of this scenario are likely to be even more deleterious than the immediate public health implications. A few grams of Cs-137 could be sufficient to halt Pakistan's economic growth and place the region into turmoil.

Availability of Radioactive Materials

Widespread availability of radioactive materials worldwide makes the threat of radiological terrorism plausible.[19] The use of radioactive materials in medicine and industry has been globalized. Radioactive materials are stored and used throughout India and Pakistan for cancer therapy, food irradiation, and medical product sterilization. The same materials that save or improve lives on a daily basis can threaten the public well being, if used by terrorist groups. From publicly available information, we have put together a small sample of the known locations where radioactive sources are used for beneficial purposes in India and Pakistan (Figure 4). As can be seen, they are spread throughout both countries and have varying levels of security.

Figure 4: Sample locations of hospitals and industrial facilities with radioactive sources that may pose a security threat.



Many of these sources have been produced in the region, but some are imported from abroad. There are many private and public suppliers of radioactive materials and each year, many of these sources are lost and can no longer be tracked. In the United States and European Union, over 370 sources are lost on an annual basis. Thousands have been lost from countries that were once part of the Soviet Union and have yet to be recovered. Additionally, there have been 643 recorded incidents of nuclear smuggling, 80 of which involved the use of radioactive materials with malevolent intent, such as extortion, bribery, and murder.[20]

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[19] See Charles Ferguson, Tahseen Kazi and Judith Perera, "Commercial Radioactive Sources: Surveying the Security Risks," Monterey Institute of International Studies (January 2003), and Peter D. Zimmerman with Cheryl Loeb, "Dirty Bombs: The Threat Revisited," *Defense Horizons* no. 38 (January 2004).

[20] Lyudmila Zaitseva and Kevin Hand, "Nuclear Smuggling Chains, Suppliers, Intermediaries, and End-Users," *American Behavioral Scientist* no.6 (February 2003), pp. 822-844, available online at newsservice.stanford.edu/news/march6/database-36.html.

Based on data available from the IAEA, India has reported several cases of stolen, and lost sources over the last few years. There have been twenty-five reported cases of missing radioactive materials. Of these, thirteen have never been recovered and 52 percent have occurred by theft.[21] Nearly 10,000 radioactive sources are used throughout India (Table 3) of which about 400 are particularly worrisome. Comparable data from Pakistan are not publicly available.

Table 3: Sealed radioactive sources used in India.

Devices	Sources	Locations
Telegamma units	**Co-60 (+DU used as shielding in some cases)**	**230**
Brachytherapy units	**Co-60, Ir-192, Cs-137, Sr-90**	**140**
Gamma irradiators	**Co-60**	**12**
Gamma chambers	Co-60	100
Industrial gamma devices	Ir-192, Co-60 (+DU)	1100
Nuclear Gauges	Am-241, Am-Be-241, Cs-137, Co-60	7500
Medical and Industrial LINACS	DU shielding	50

Source: A. Kumar, S.P. Agarwal, U.B. Tripathi, B.K.S. Murthy, and B.C. Bhatt, "Safety and Security of Radioactive Materials - the Indian Scenario." Bhabha Atomic Research Center (1998).

The efficacy of existing radiological regulatory practices in India and Pakistan remains opaque to outside analysts. Typically, only one or two radiation safety officers control each source in hospitals, research laboratories, and industrial plants.[22] Security practices are sometimes deficient. On August 17, 2003, the *Times of India* reported that individuals in Jamshedpur, India stole small gauges filled with Co-60.[23] These deficiencies are by no means confined to India or Pakistan. The US Department of Energy has compiled a list of recommendations to upgrade security at US facilities, including the following measures:

- Establish a national RDD protection level
- Develop a national threat policy
- Initiate development of a national source tracking system
- Develop an integrated national response strategy for rapid recovery of unsecured sources
- Develop an integrated national strategy for disposition of unsecured sources

[21] A. Kumar, S.P. Agarwal, U.B. Tripathi, B.K.S. Murthy, and B.C. Bhatt, "Safety and Security of Radioactive Materials - the Indian Scenario," Bhabha Atomic Research Center (1998).

[22] Interview with A. Gopalakrishnan, former Chairman of the Atomic Energy Regulatory Board of the Government of India.

[23] "Radioactive Material Worth Rs.1.5 Mn Stolen," *Times of India* (August 17, 2003).

- Enhance coordination and communication among governmental agencies
- Continue coordination with the IAEA[24]

Every country that possesses poorly guarded, RDD-"usable" radiological materials has a responsibility to improve public safety and to guard against radiological terrorism.

Terrorist Detonation of a Low-Yield Nuclear Weapon

This section posits scenarios involving the detonation of a low-yield nuclear weapon. There are five basic nuclear weapons effects. "Blast and shock effects are the primary damage-producing mechanisms for soft targets such as cities and are often the only effective mechanism for destroying underground structures such as missile silos."[25] Immediately after a nuclear explosion, a high-pressure wave moves from ground zero outwards. This wave is usually reflected off the ground creating a secondary blast wave. "Overpressure" is a key measurement of the strength of the blast wave and can be defined as "the pressure in excess of the normal atmospheric value."[26] Thermal effects are responsible for producing burns and eye injuries and could also lead to the ignition of combustible materials. Fire damage from a nuclear detonation has historically been viewed by the United States military as difficult to quantify but may result in up to five times the amount of damage from nuclear blast. The fourth effect is radiation. There are two types of radiation: initial radiation, which is emitted within the first minute after a detonation, and residual radiation, which is emitted thereafter. Residual radiation leads to the "fallout" effect. Finally, there is the electromagnetic pulse effect. This effect occurs at the moment of nuclear detonation. It can be thought of as a very strong electrical disturbance akin to an extremely powerful, fast, and expansive bolt of lightning. This effect will be discussed in greater detail below.[27]

Electromagnetic Pulse – An Invisible Effect

Simulations help visualize the physical and health damage that would result from nuclear blasts. Here we describe an easily overlooked weapons effect, electromagnetic pulse (EMP). EMP is a short but extremely powerful electrical disturbance, akin to a very strong and very fast

[24] "Radiological Dispersal Devices: An Initial Study to Identify Radioactive Materials of Greatest Concern and Approaches to Their Tracking, Tagging, and Disposition," Report to the Nuclear Regulatory Commission and the Secretary of Energy (May 2003).

[25] Federation of American Scientists, "Special Weapons Primer: Nuclear Weapon Blast Effects," (October 21, 1998), available online at http://www.fas.org/nuke/intro/nuke/blast.htm.

[26] Samuel Glasstone and Philip Dolan, "The Effects of Nuclear Weapons," Third Edition (US Department of Defense: 1977), p. 38.

[27] Steve Fetter, "The Effects of Nuclear Detonations and Nuclear War," in Graham T. Allison Jr., Robert D. Blackwill, Albert Carnesale, Joseph S. Nye Jr., and Robert P. Beschel Jr. (eds.), *A Primer for the Nuclear Age*, Occasional Paper no. 6 (Center for Science and International Affairs, Harvard University, Cambridge, MA: 1990), pp. 23–30.

bolt of lightning. It disables electronics and communications equipment almost instantaneously. It has two primary modes of damage: physical damage, such as shorts and burnouts, and temporary operational instabilities, such as power loss and fluctuation. The EMP is particularly devastating to advanced electronics, such as computers, servers, avionics equipment, and other technologies. Older technologies, such as motors and vacuum tubes, are less susceptible. EMP effects can devastate civilian infrastructure. As a Pentagon EMP expert has noted, "The EMP robustness of the civilian infrastructure of the United States can be summarized…[as being] entirely non-existent. Our civilian telephone, electricity, broadband communications, and electrical plants are all naked".[28] Moreover, in the United States, 95 percent of military communication routes through civilian systems.[29] EMP effects can also severely hamper military command, control, communications and intelligence. Referring to battlefield operations in the event of a low-yield nuclear weapon, a Marine Corps officer writes that, "The Marine Corps…will have problems with the EMP…The command control systems will be knocked out. The generals and their staff will not be able to talk to their front line troops and they will not be able to receive instructions from higher headquarters in the United States."[30]

The EMP effect is not limited to a high-yield weapon. At low yields, the EMP effect can also be extremely intense, as this effect is only weakly dependent on yield. Although there is a 100,000 percent increase in weapon yield from a one KT device to a ten-megaton device, the maximum EMP effect only increases by twenty-five percent.[31] Using basic EMP calculations, we have been able to show that the EMP effects from a low-yield surface burst would far outdistance the blast and fire damage. Although the blast would destroy an area of approximately one square kilometer, the EMP from the nuclear detonation would be twenty-five times as large. Most of the electronics and communications capacity in this region would be ruined. If a nuclear weapon detonated near the Gateway of India in Mumbai (see scenario below), the blast effects would not reach out to the Mumbai stock exchange, but the EMP effect would be devastating. The greatest EMP effects would occur within the twenty-five square kilometers surrounding the blast, but even out to almost 100 square kilometers, the EMP damage would be significant.

Post-detonation complications would be severe. Electronics and communication systems may be inoperable. Power grids may be affected in an area even outside the city limits. If this were to occur, communication among and between leaders could be compromised, as would be their transportation. With planes and helicopters using advanced avionics and with air trafficking systems affected, it is unclear whether transportation would be feasible. It took the United States and Soviet Union decades to harden military nodes against EMP, and they are still susceptible to

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[28] Testimony by Dr. Lowell Wood before the House Armed Services Committee (October 7, 1999).

[29] Statement by Congressman Curt Weldon at the Committee on National Security, Military Research and Development Subcommittee (October 16, 1997).

[30] Major R. D. Erick, United States Marine Corps, "EMP," Masters thesis (April 6, 1984).

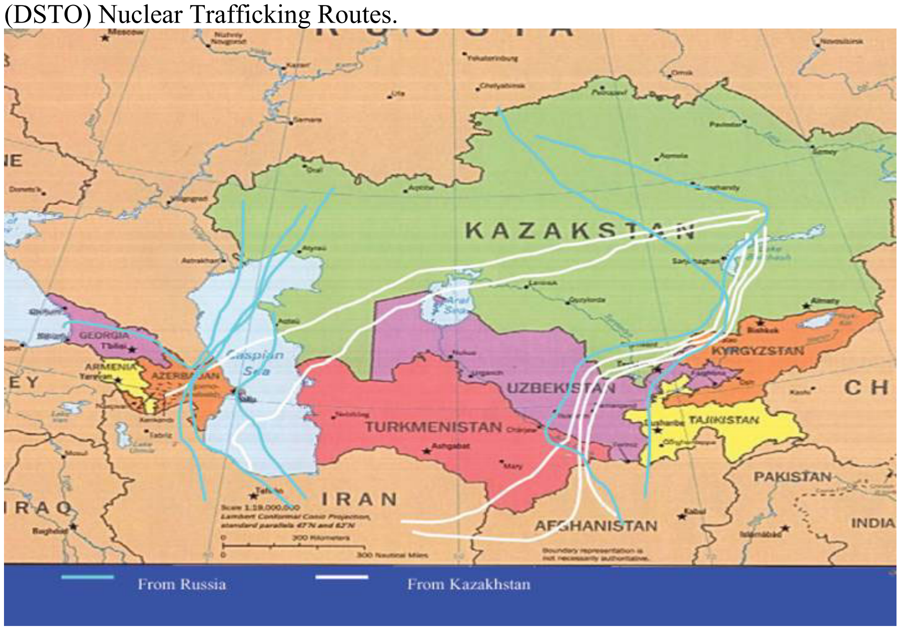
[31] Glasstone and Dolan, "The Effects of Nuclear Weapons: Chapter 7, Electromagnetic Pulse Phenomena," Redacted version obtained through FoIA by the Arms Race and Nuclear Weapons Research Project (Institute for Policy Studies: Washington DC).

considerable damage. Just as importantly, US civilian systems are fully unprotected against such an attack.

Fissile Material Availability

The severe damage caused by a nuclear weapon necessitates an examination of how non-state actors might acquire such a capability. Although estimates vary, the production of a functional nuclear weapon may require only a few kilograms of plutonium or about fifteen to twenty-five kg of uranium. Reports of theft or unaccounted for nuclear material are widespread and have recently been compiled by Stanford University's Institute for International Studies (IIS). The Database on Nuclear Smuggling, Theft and Orphan Radiation Sources (DSTO) has reported that about "forty kilograms of weapons-usable uranium and plutonium have been stolen from poorly protected nuclear facilities in the former Soviet Union during the last decade."[32] Although most of this material has since been retrieved, there still remains two kilograms of highly enriched uranium that is unaccounted for. A researcher at the IIS argues that "this is the tip of the iceberg" and that more than ten times that amount might actually be missing. In 1998, the Russian Federal Security Services (FSB) thwarted a plan by nuclear facility employees to divert 18.5 kg of HEU.[33] Had this not occurred, there would have been almost enough fissile material to produce

Figure 5: Database on Nuclear Smuggling, Theft and Orphan Radiation Sources (DSTO) Nuclear Trafficking Routes.



Source: Chaim Braun, Fritz Steinhausler, and Lyudmila Zaitseva "International Terrorist Threats to Nuclear Facilities," Center for International Security and Cooperation, Presentation at the American Nuclear Society, (Washington DC: November 19, 2002).

[32] Lisa Trei, "Database Exposes Threat from 'Lost' Nuclear Material," *Stanford Report* (March 6, 2002).

[33] Lyudmila Zaitseva and Kevin Hand, "Nuclear Smuggling Chains, Suppliers, Intermediaries, and End-Users," *American Behavioral Scientist* v. 46, no. 6 (February 2003), pp. 822-844.

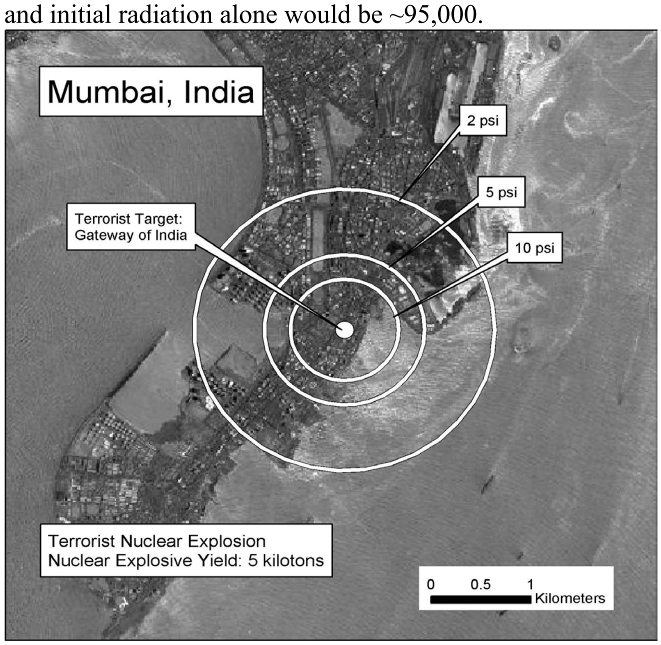
a nuclear weapon. There are no binding IAEA standards of protection, accountancy, and security for weapon-grade material, and most states would be reluctant to accept intrusive foreign assistance to upgrade existing practices

Stolen nuclear material can reach its destination by many different routes. Stanford University's DSTO monitors trafficking routes, and as can be seen, these routes snake through Central Asia toward South Asia (Figure 5). An instance of nuclear terrorism involving HEU or plutonium would have very grave consequences. The likelihood of this eventuality is perhaps less than the likelihood of radiological terrorism involving the use of a dirty bomb, but the consequences would obviously be far greater. More scientific skills would be needed to produce a nuclear weapon utilizing stolen HEU, and the material handling challenges associated with a plutonium bomb would be quite severe. Nonetheless, the possibility of nuclear terrorism using HEU or plutonium cannot be discounted in South Asia or elsewhere. We therefore analyze two scenarios based on the detonation of a five-kiloton yield device in Mumbai and a similar-sized nuclear weapon detonated in Islamabad.

Terrorist Nuclear Detonation: Mumbai, India and Islamabad, Pakistan

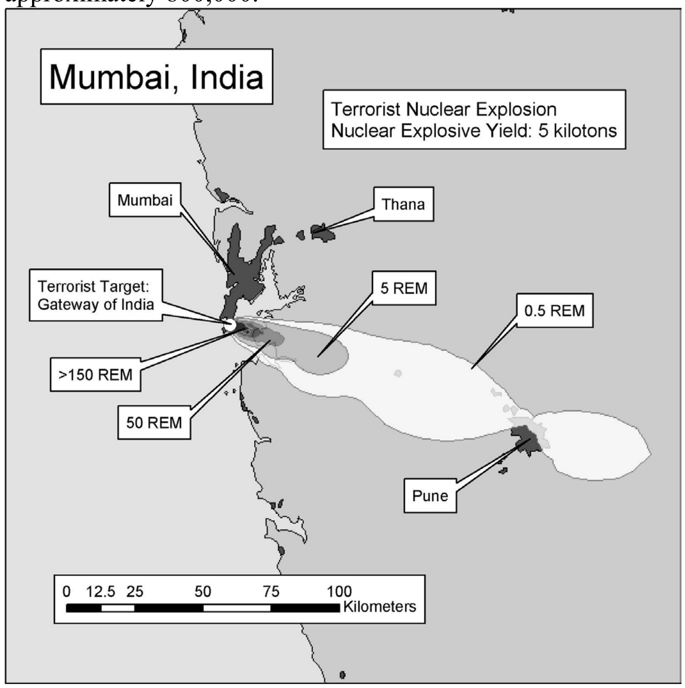
Figure 6a shows the blast effects of a five-kiloton nuclear weapon detonated near the Gateway of India in Mumbai. It should be noted that in the summer of 2003, the Gateway and Mumbai's jewelry market, Zaveri Bazaar, were the locations of terrorist attacks using conventional bombs that led to the death of at least fifty people. The different circles correspond to different levels of blast overpressure, moving concentrically outwards from ground zero as the pressure and damage decrease.

Figure 6a (Mumbai): 5 KT Nuclear weapon and corresponding blast radii. Prompt casualties from the blast and initial radiation alone would be ~95,000.



Source: Satellite Photo: Space Imaging.

Figure 6b (Mumbai): 5 KT Nuclear weapon and corresponding fallout contours. Total fallout casualties are approximately 800,000.



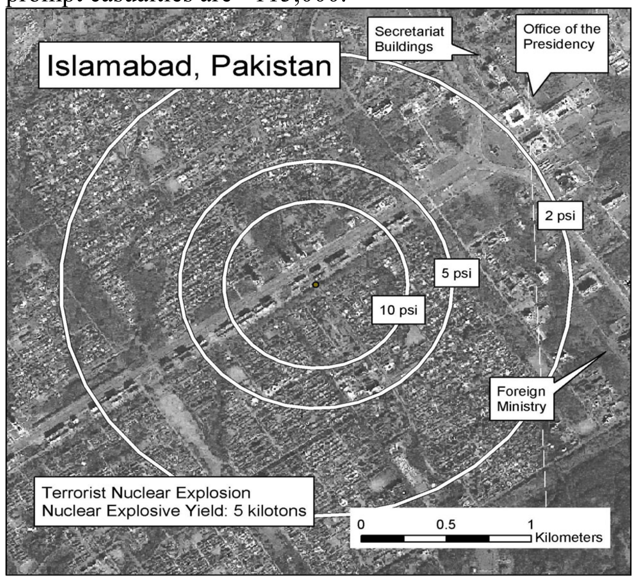
Source: Satellite Photo: Space Imaging

In the innermost zone, corresponding to ten pounds per square inch of overpressure, most structures will be severely damaged or destroyed. Nearly everyone in this area will die from the blast. Out to the second zone, corresponding to five pounds per square inch of overpressure, most buildings will collapse. Nearly everyone within this zone will be injured and fatalities will be common. Out to the third zone, residential structures will collapse. Serious injuries would be frequent and fatalities may occur. From the prompt effects, which include blast/thermal effects as well as initial radiation, the model indicates there will be approximately 95,000 casualties.

In addition to the prompt effects, the fallout in Mumbai (Figure 6b) from a five KT nuclear weapon would traverse a linear distance of 100 kilometers. The fallout cloud would encompass more than 600 square kilometers. Fallout effects would be strongest within the first forty-eight hours after the detonation by which time the fallout radiation will have fallen to one percent of its initial value. Fallout patterns also depend heavily on weather conditions. A bomb detonated in Mumbai could have considerable fallout effects over a city as far away as Pune. For Mumbai, our model indicates that there would be nearly 800,000 fallout casualties from this nuclear explosion. With radiation particles traveling along wind currents and through the atmosphere, much of western India would likely experience a noticeable increase in background radiation.

Figure 7a details similar blast effects and contours for Islamabad. In this scenario, the model predicts approximately 115,000 casualties.

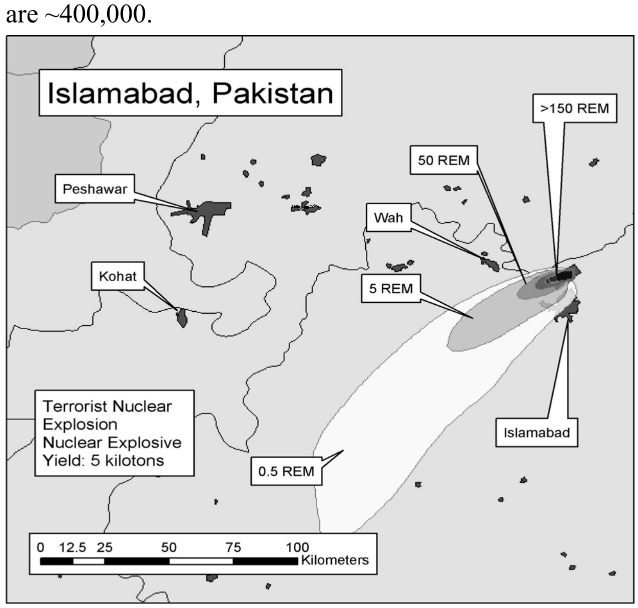
Figure 7a (Islamabad): 5 KT Nuclear weapon and corresponding blast radii in Islamabad, Pakistan. Total prompt casualties are ~115,000.



Source: Satellite Photo: Space Imaging

A similar analysis for Pakistan can be seen in Figure 7b. People living more than 100 km away from a blast in Islamabad would be exposed to serious radiation. Total casualties due to fallout are estimated to be nearly 400,000. Depending on the prevailing winds, fallout could easily extend across the Line of Control dividing Kashmir or across the International Border into India.

Figure 7b (Islamabad): 5 KT Nuclear weapon and corresponding fallout contours. Total fallout casualties are ~400,000.



Source: Satellite Photo: Space Imaging

These calculations for a five KT nuclear device detonated in Mumbai and in Islamabad are far in excess of the fatalities produced at Hiroshima and Nagasaki, which were approximately 100,000 fatalities for each detonation. While the yield of the postulated terrorist attack here is five KT, the much higher South Asian population densities near ground zero, combined with additional casualties from fallout, produce significantly higher estimates in India and Pakistan than for the higher yield weapons used against Japan to end World War II.

Non-state actors continue to have access to fissile materials from sources outside of South Asia. Given the existence of nuclear trafficking routes near South Asia, the possibility exists that fissile material could reach an Indian or Pakistani city. Our simulations suggest that even a low-yield nuclear weapon detonated by a terrorist would produce devastating physical and economic damage that could cripple a major metropolitan area in either India or Pakistan. Fallout effects would stretch over vast areas of land and might even cross borders.

Accidental Nuclear Detonations

Accidents could occur as a result of a weapon-handling incident, a fire, a conventional attack against a nuclear target, a ground transportation accident, a malfunction of an aircraft carrying a nuclear device, or by other means. Although at this time it is believed that neither India nor Pakistan have deployed their nuclear weapons, the possibility of accidents still remains. More importantly, the likelihood of accidents occurring will increase in the event of deployment, or during movement of nuclear assets in a crisis environment.

A nuclear weapon could detonate because of a failure of its safety mechanisms. Over time, the United States developed safety mechanisms for its nuclear weapons. In the US, safety devices and policy guidelines minimize the probability of a chain reaction in the event of an accident. The "one-point" safety policy stipulates that "the probability of achieving a nuclear yield greater than four pounds of TNT equivalent in the event of any one-point initiation of the weapon's high explosive will not exceed one in 10^6."[34] The achievement of this directive was made possible only through decades of nuclear weapons research and testing. The United States conducted 88 nuclear detonation safety tests from 1945-1990 with the explicit purpose of confirming that "a nuclear explosion will not occur in case of an accidental detonation of the explosive associated with the device."[35] The Soviet Union conducted forty-two such tests.[36] New nuclear powers might find it difficult to ensure such high levels of safety due to the limitations of technology, research, and nuclear testing. Consequently, these states might have difficulty preventing detonations in the event of nuclear accidents.

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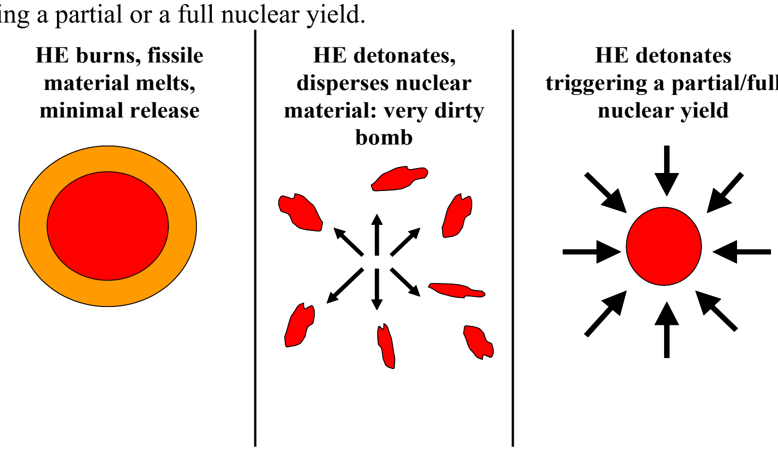
[34] US Department of Energy, Order DoE 5610.10 (October 10, 1990).

[35] United States Nuclear Tests (July 1945 through September 1992), available online at http://www.fas.org/nuke/guide/usa/nuclear/nv209nar.pdf.

[36] Available online at http://nuclearweaponarchive.org/Russia/Sovtestsum.html.

Different types of accidents can produce different effects (Figure 8). One possible accident scenario involves the burning of a weapon's high explosives around the fissile core, which could cause the fissile material in the core to melt. In this event, radioactive contamination would occur without a nuclear detonation. Cleanup would be expensive but manageable. Another scenario involving a plutonium bomb would entail a detonation of high explosives that does not produce a nuclear yield, but instead disperses radioactive plutonium in the surrounding region. This scenario can be described as a "very dirty bomb" and would be similar to RDDs using alpha sources. A far more alarming accident scenario would entail the detonation of a weapon's high explosives triggering a nuclear yield. This nuclear yield could range from being a very small fraction of the intended yield to the total intended yield of the weapon. The span of potential yields is important because in the lowest fractional yields it might initially be difficult to differentiate between a nuclear blast and a conventional one.

Figure 8: Schematic drawing of three possible types of accidental nuclear detonation. A) High explosive (HE) burns and the fissile material melts. B) HE detonates and disperses the radioactive material into the surrounding area. C) HE detonates thereby triggering a partial or a full nuclear yield.



Source: Z. Mian, M. V. Ramana, and R. Rajaraman "Risks and Consequences of Nuclear Weapons Accidents in South Asia," PU/CEES Report no. 326 (September 2000).

Nuclear weapons accidents have happened in the past and they will undoubtedly occur in the future. It has been reported that between the United States, Great Britain, France, and the former Soviet Union, there have been 230 nuclear accidents.[37] In the United States alone, there are more than ten documented cases where the high explosives surrounding the fissile cores have detonated. Of these, two produced a dispersal of nuclear material over an expansive area – Palamores, Spain in 1966 and Thule, Greenland in 1968.[38] In Palamores, it cost over $100 million to cleanup and repair the damage that was done to the surrounding environment. Luckily for all

[37] Z. Mian, M. V. Ramana, and R. Rajaraman, "Risks and Consequences of Nuclear Weapons Accidents in South Asia," PU/CEES Report, no. 326 (September 2000).

[38] Steve Fetter and Frank von Hippel, "The Hazard from Plutonium Dispersal by Nuclear-warhead Accidents," *Science and Global Security* v. 2, no. 1 (1990), pp. 21–41.

involved, the area where the accident occurred was not populated and the health effects were minimal.[39] In Thule, four nuclear bombs carried by a B-52 bomber were engulfed in flames after the aircraft crashed. The high explosives surrounding each nuclear core detonated, resulting in the dispersal of nuclear material. It should be noted that in the case cited above, the B-52 was on alert. Subsequent to this accident, alert practices for US strategic bombers changed. National leaders in India and Pakistan are sensitive to the risks associated with maintaining nuclear alerts, and are unlikely to follow many dangerous Cold War practices.

Accident Modeling

For the purpose of this analysis, we chose two airbases, one in India and one in Pakistan, where a nuclear accident could take place. We have no knowledge of whether nuclear weapons are stored in these bases nor do we have any reason to believe that they are. We chose the Amritsar airbase in India primarily to illustrate how events at a military installation could affect a nearby civilian urban center. In addition, its proximity to the International Border suggests significant ramifications in the event of fallout. The Mashroor Airbase in Karachi was also selected for its size and importance, proximity to an urban center, and its location in the key port of entry for Pakistan. The simulation at the Mashroor Airbase has not been included in this essay as the results closely resemble those of the Amritsar scenario.

The simulations that we use for the accident modeling have two distinct stages: the nuclear accident model and the nuclear detonation model. As stated earlier, it is likely that an accident will not lead to the intended nuclear yield, but will instead be a much smaller fraction of that yield or produce no fission yield at all. As such, the plume characteristics and the general dynamics of the explosion will be different. The nuclear accident model takes these differences into account for all explosions less than ten tons fission yield, including when there is no fissile yield. The nuclear detonation model, which is similar to the one employed in the terrorist nuclear weapon analysis, takes over for the larger fission yields, including one KT and five KT. The analysis will step through a series of different fractional yields, starting with plutonium dispersal and no fissile yield all the way through a full yield of five KT.

Nuclear Weapon Accident at Amritsar Air Base - Amritsar, India

In the event of an accident, it is possible that the high explosive surrounding a fissile core will detonate. If that detonation is below a certain level or does not have the right symmetry, however, there will be no fission reaction in the nuclear core. Instead, it is likely that the plutonium core will be fractured and will disperse into the surrounding area (Figure 9a). Since there is no nuclear yield, it will be initially ambiguous as to whether or not radiation was released. It is likely that military or civilian officials will not know right away, and it is unclear whether

[39] Ibid.

they would acknowledge that such an accident had taken place. If there is no public knowledge of radiation dispersal, people will not evacuate the contaminated area and a large number could suffer high levels of radiation exposure. The short-term deaths will mainly come from the conventional blast (which could be considerable in this case with 500 pounds of TNT), but the entire area in the outer circle would be contaminated. The cleanup would be difficult and expensive and most importantly, it may take days or weeks before the people in the city of Amritsar are made aware of such an accident. Over 10,000 people could die over the long term due to cancer as a result of this explosion. More than fifteen square kilometers would be contaminated and would require evacuation and cleanup.

Figure 9b shows an accidental detonation with one-ton fission yield. This is the same size as many conventional bombs. Based on blast effects, it might not be initially obvious that a nuclear yield had taken place. As such, it is unclear how long it would take to make that assessment. Since evacuating within the first twenty-four to forty-eight hours is crucial to avoiding fallout casualties, the ambiguity of the blast could result in high casualties due to weapon effects. The blast and radiation effects from such an explosion would lead to 120,000 fallout casualties and approximately 230 prompt casualties. Most individuals on the airbase would either die from the blast or from high levels of radiation exposure. Most of the fallout casualties would be civilians in the city of Amritsar.

Figure 9c represents a five-ton fission yield. Prompt casualties are estimated to be 1,600. The area that would be exposed to fallout is greater than 100 square kilometers. Fallout casualties will be the same as for a one-ton fission yield, 120,000 casualties, because the additional area exposed is sparsely populated. Figure 9d corresponds to ten tons fission yield, or 20,000 pounds of TNT. This is about the size of the largest conventional bomb in the US arsenal, the massive ordinance aerial blast (MOAB). Because this scenario would include a much larger blast, it might be a little less ambiguous that a nuclear detonation has occurred. However, since most individuals on the base would be fatalities or casualties, and most communications would be compromised, ambiguity might remain. Prompt casualties are estimated to be greater than 6,000, and the fallout numbers are correspondingly larger. Superimposing the contours on a larger map (Figure 9e) one can see the fallout extending quite far. Depending on the prevailing winds, the fallout could easily cross over the International Border into Pakistan and fallout effects could be felt as far away as Lahore.

Figure 9f shows the effects of a one KT yield. It is important to note that the dynamics of this yield are considerably different from the previous scenarios because much more of the nuclear material is now undergoing fission. Because the base is situated away from the city, prompt casualties are estimated to be around 9,000. The fallout casualties, however, are estimated to rise to over 300,000 with an area of over 400 square kilometers being exposed. Finally, as shown in Figure 9g, a full five KT nuclear yield increases the prompt casualties dramatically because the strongest radiation effects and the blast radius reach out much further than before and well into the urban center. We estimate around 100,000 prompt casualties and nearly 700,000 fallout casualties in this scenario. Figure 9h shows on a larger scale how, depending on the winds, the plume could easily extend into Pakistan.

The effects of an accidental nuclear blast with fissile material detonated, or even just dispersed, could put thousands of civilian and military lives in peril. It is imperative that cities close to a nuclear accident be evacuated immediately so as to limit the effect of nuclear fallout. Fallout effects are greatest within the first forty-eight hours of a nuclear detonation. Any delay on the part of governments might lead to unnecessary casualties. In addition, the confusion and ambiguities that would surround a nuclear accident demonstrate the potential for escalation across borders.

Amritsar Airbase Nuclear Accident
High Explosive: 500 lbs. TNT
Fissile Material: 6.1 Kg Pu

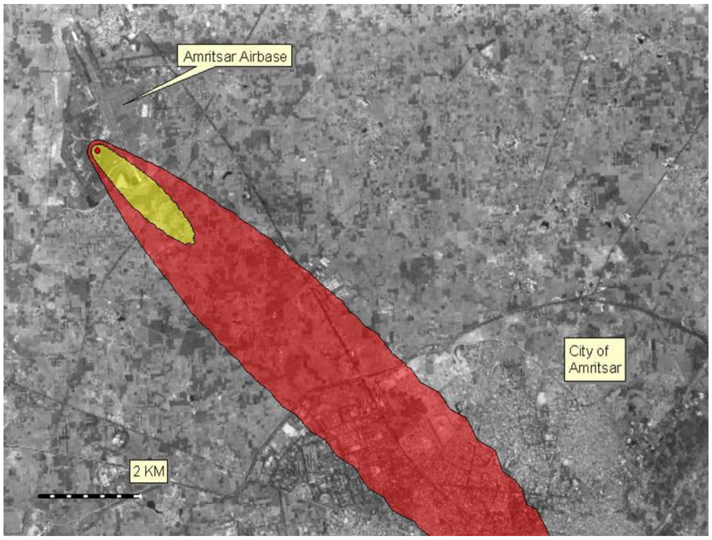


Figure 9a: HE Detonation with no fission yield
Short Term Deaths: ~10
Long Term Cancer Deaths: ~10,000

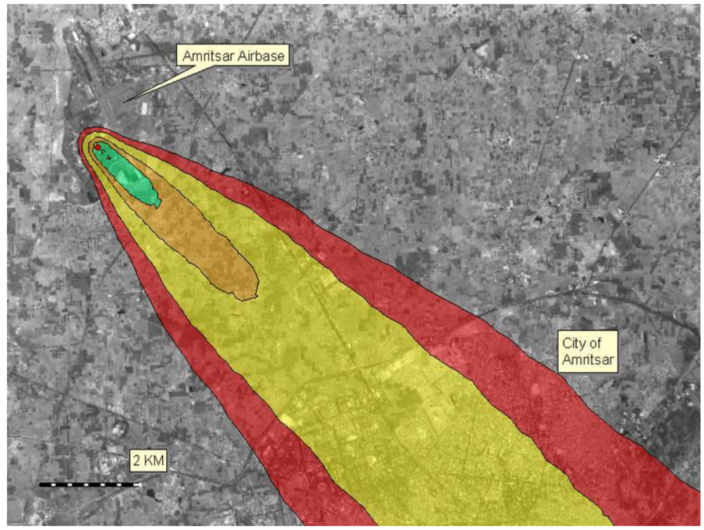


Figure 9b: 1 Ton Fission Yield
Prompt Casualties: ~200
Fallout Casualties: ~120,000

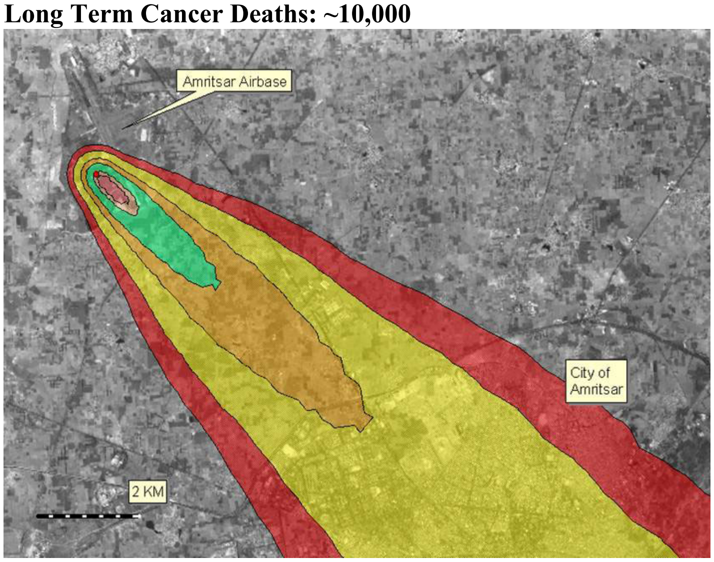


Figure 9c: 5 Ton Fission Yield
Prompt Casualties: ~1,600
Fallout Casualties: ~120,000

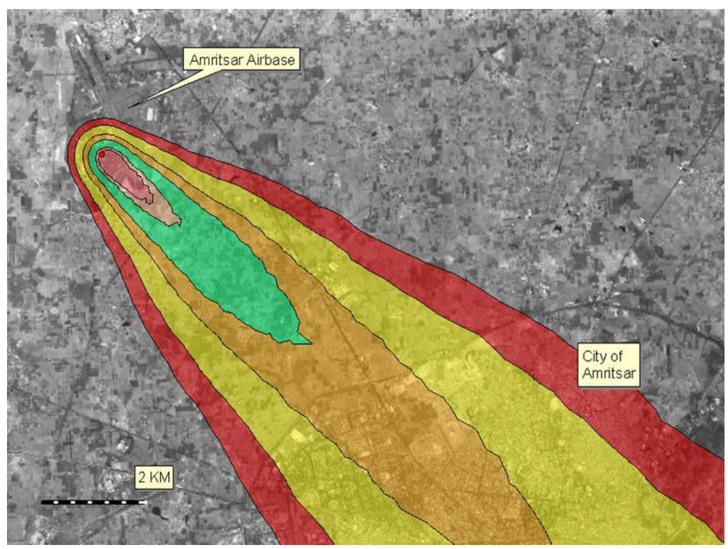


Figure 9d: 10 Ton Fission Yield
Prompt Casualties: ~6,000
Fallout Casualties: ~150,000

Source: Satellite Photo: Space Imaging

Amritsar Airbase Nuclear Accident
High Explosive: 500 lbs. TNT
Fissile Material: 6.1 Kg Pu

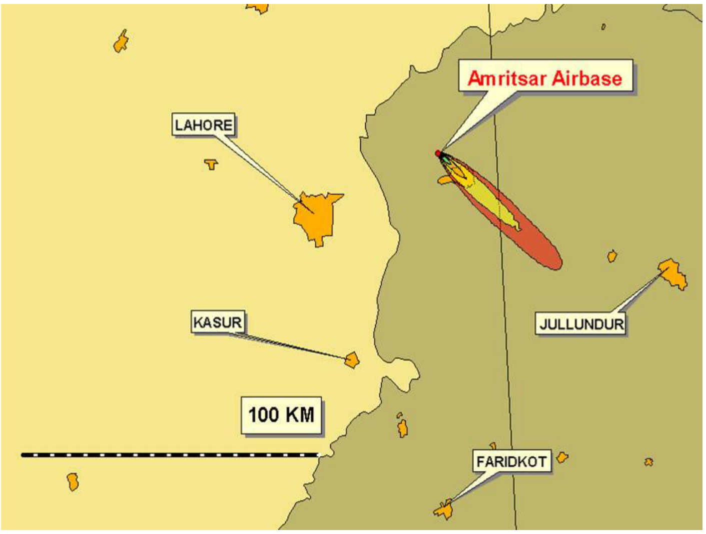


Figure 9e: Large-Scale view of 10 Ton Fission Yield
Prompt Casualties: ~6,000
Fallout Casualties: ~150,000

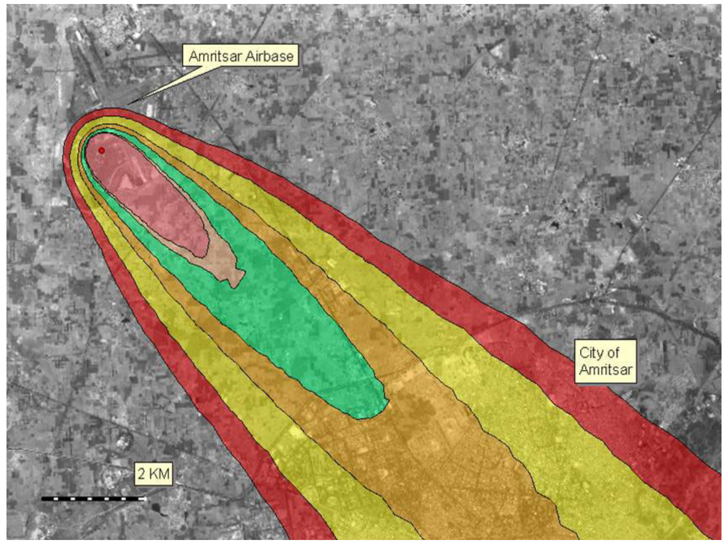


Figure 9f: 1 Kiloton Fission Yield
Prompt Casualties: ~9,000
Fallout Casualties: ~300,000

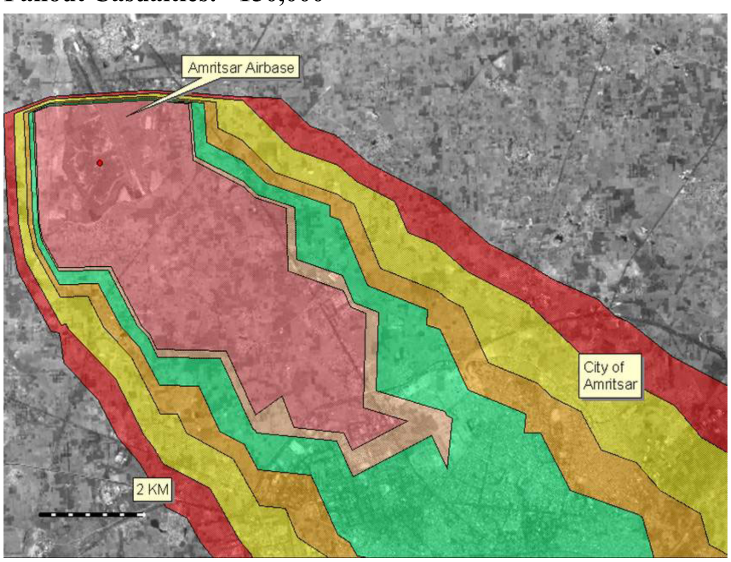


Figure 9g: 5 Kiloton Fission Yield
Prompt Casualties: ~100,000
Fallout Casualties: ~650,000

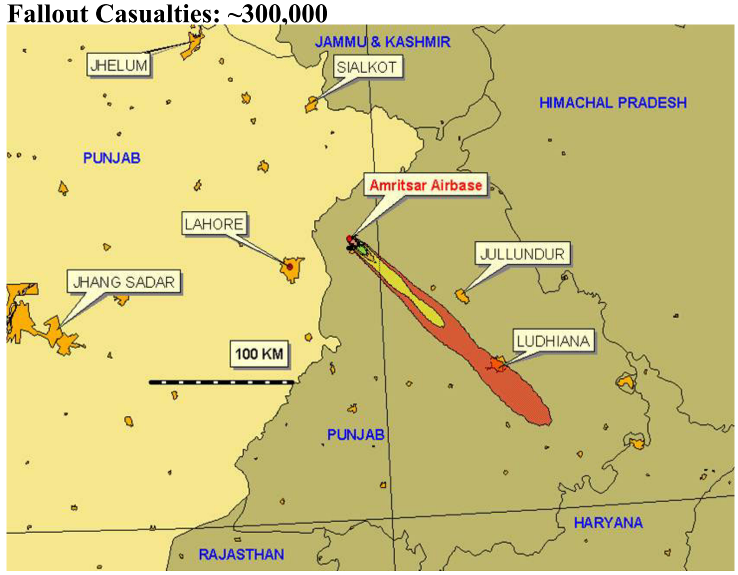


Figure 9h: Large-Scale view of 5 Kiloton Fission Yield
Prompt Casualties: ~100,000
Fallout Casualties: ~650,000

Source: Satellite Photo: Space Imaging

Nuclear Forensics

In the event of a nuclear terror attack or an accidental nuclear detonation, knowing the source or point of origin of the fissile material would be highly valuable. Many countries possess sensors and equipment to help monitor and identify nuclear explosions. These assets are capable of providing information about the location and yield of the blast. In addition, some information about weapon type and design can also be derived with sophisticated technologies, especially if access to the site of the explosion is granted. There are some countries and organizations, such as the United States, the International Atomic Energy Agency, and the Comprehensive Test Ban Treaty Organization, that have the ability to engage in nuclear forensics. The four primary modes of earth-based analysis include seismic, hydro-acoustic, infrasound, and radionuclide. The United States also has satellite-based technologies that can help in monitoring and detection. When diagnosing a nuclear explosion, there are two basic groups of detection technologies: those that produce results in minutes, hours and days; and those that require days, weeks or sometimes even months. In the first grouping, infrasound detects sounds waves from atmospheric and shallow-buried explosive. Seismic sensors detect shock waves from underground explosions and can help determine yield and location. Hydro-acoustic systems detect explosions under or near the surface of the oceans. Satellite sensors help with detecting location and yield. Radionuclide monitoring can be especially useful as a forensic tool and for attribution purposes. Radionuclide testing detects radioactive gasses or particulates from atmospheric or vented sub-surface explosions. This can be used to determine fuel type (HEU or plutonium), enrichment levels, and design information. This technology can help create a nuclear "fingerprint" of the material at hand to help identify its origin. As with all fingerprints, however, this information is only useful if it can be matched up against known source material. To properly attribute the origin of fissile material might require highly sensitive technical data with which countries might not be willing to part.

The difficulty in identifying the point of origin of nuclear materials used by a terrorist group could result in a crisis in which responsibility for the event is hard to assign. This, in turn, could create conditions for a severe crisis on the subcontinent with the potential for unintended escalation.