Possession and Deployment of Nuclear Weapons in South Asia

An Assessment of Some Risks

This paper examines some of operational requirements and the dangers that come with the possibility that in the foreseeable future India and Pakistan may deploy their nuclear arsenals. The authors first describe the analytical basis for the inevitability of accidents in complex high-technology systems. Then they turn to potential failures of nuclear command and control and early warning systems as examples. They go on to discuss the possibility and consequences of accidental explosions involving nuclear weapons and their delivery systems. Finally some measures to reduce these risks are suggested.

R Rajaraman, M V Ramana, Zia Mian

As citizens of nuclear armed states, the people of India and Pakistan must confront the risks that go with possessing nuclear weapons. There is some public awareness of the holocaust that results when nuclear bombs are used in warfare, a legacy of the ghastly attacks by the US on the Japanese cities of Hiroshima and Nagasaki over five decades ago. But experience in the nuclear weapons states shows that grave dangers attend even the mere possession and deployment of nuclear weapons, not just when they are used deliberately in war.

Deployment means keeping the warheads that contain nuclear explosives attached to delivery vehicles, ballistic missiles or aircraft, and having them ready to be used to attack a designated target. In the case of the US and Russia, cold war crises, military planning, technological advancement, and nuclear doctrines that are tied closely to each other have ensured that even now many of their nuclear weapons are deployed on a high state of alert, ready to be launched in a matter of minutes. From all that we know publicly, India and Pakistan are yet to deploy their missiles and bombers with nuclear warheads. Nevertheless the same factors which led the US and Russia to deploy their weapons are also evident in south Asia.

Indeed, there have been reports of nuclear forces being readied for use during periods of crises. Bruce Riedel, formerly the Senior Director for Near East and South Asian Affairs at the US National Security Council, has disclosed that the "Pakistanis were preparing their nuclear arsenals for possible deployment" during the 1999 Kargil crisis.[1] Similarly, Raj Chengappa, a senior journalist with *India Today* with access to defence personnel, reported that during the Kargil crisis, India "activated all its three types of nuclear delivery vehicles and kept them at what is known as Readiness State 3 – meaning that some nuclear bombs would be ready to be mated with the delivery vehicles at short notice… Prithvi missiles were deployed and at least four of them were readied for a possible nuclear strike. Even an Agni missile capable of launching a nuclear warhead was moved to a western Indian state and kept in a state of readiness".[2] More recently, there were a few reports that as part of the military mobilisation following the December 2001 attack on India's parliament and the subsequent crisis following the May 2002 attacks in Kashmir, Pakistan and India had deployed nuclear weapons.[3]

There is good reason to fear that the operational deployment of nuclear weapons may become a permanent condition in the foreseeable future. The most official guide to India's intended nuclear posture is the August 1999 Draft Nuclear Doctrine (DND) released by the National Security Advisory Board.[4] It states that "India shall pursue a doctrine of credible minimum nuclear deterrence" and that this in turn requires that India maintain: (a) sufficient, survivable and operationally prepared nuclear forces, (b) a robust command and control system, (c) effective intelligence and early warning capabilities, (d) planning and training for nuclear operations, and (e) the will to employ nuclear weapons.[5]

The requirement for India to have 'operationally prepared' nuclear forces is usually interpreted to mean deployment of nuclear weapons on delivery vehicles. Deployment of India's nuclear weapons would, according to the DND, involve a "triad of aircraft, mobile land-based missiles and sea-based assets" structured for 'punitive retaliation' so as to 'inflict damage unacceptable to the aggressor'. The DND envisages "assured capability to shift from peacetime deployment to fully employable forces *in the shortest possible time*" (emphasis added).

Pakistan does not have a comparable document detailing its envisaged nuclear policy. One of the closest contenders is a newspaper article authored by three leading Pakistani statesmen, Agha Shahi, Zulfiqar Ali Khan and Abdul Sattar. They recommend that "In the absence of an agreement on mutual restraints, the size of

Pakistan's arsenal and its deployment pattern have to be adjusted to ward off dangers of pre-emption and interception." They also suggest that "A high state of alert will become more necessary as India proceeds with deployment of nuclear weapons".

All of these raise the possibility that in the foreseeable future India and Pakistan may deploy their nuclear arsenals. In this paper we examine some of operational requirements and the dangers that come with such deployment. We first describe the analytical basis for the inevitability of accidents in complex high-technology systems. Then we turn to potential failures of nuclear command and control and early warning systems as examples. We go on to discuss the possibility and consequences of accidental explosions involving nuclear weapons and their delivery systems. Finally we suggest some measures to reduce these risks.

Accidents in Complex Systems

Almost 20 years ago, sociologist Charles Perrow analysed a variety of accidents involving complex technological systems, including the Three Mile Island nuclear reactor, various petrochemical plants, ships and aircraft and more. He identified two structural features of these technologies – 'interactive complexity' (sub-systems interacting in unexpected ways) and 'tight coupling' (sub-systems having rapid impact on each other) – which make them accident prone.[6] Perrow coined the term 'normal accidents' to explain how serious accidents appear to be an inevitable consequence of such technologies, regardless of the intent or skill of their designers or operators. Other scholars have applied the same insights to a variety of different systems.

Normal accident theorists highlight the interplay between complex technologies, the organisations and bureaucracies controlling them and society at large. The rigid and hierarchical nature of many organisations that operate high-technology systems prevents the vertical flow of information from the field to the controlling administration. At the same time, the compartmentalisation of different wings of such organisations suppresses horizontal flow of information. These affect the ability of individuals in these organisations to recognise signals of potential failures and react appropriately. Some of these factors in the case of the US National Aeronautics and Space Administration (NASA) were responsible for the January 1986 explosion of the Challenger space shuttle. In analysing this, sociologist Diane Vaughan observed that the ultimate origins of the accident "were in routine and taken-for-granted aspects of organisational life that created a way of seeing that was simultaneously a way of not seeing".[7]

Large bureaucratic organisations also exhibit a tendency to downplay the possibility of failures for fear of the reputation and even their budgets. This is reflected in a lack of recognition of all possible contingencies and not incorporating adequate safety measures. This sense of infallibility is particularly marked in institutions that are characterised by 'expertise' and 'discipline' and further compounded where national security is involved.

More than any other, systems for the command and control of nuclear weapons possess these characteristics. Political scientist Scott Sagan, in an important and wide-ranging study of several decades of experience with nuclear weapon systems in the US, identified a number of accidents, close calls and near misses and concluded that while on any given day the risk of a serious nuclear weapons accident may be low, in the long run such an accident is extremely likely.[8] Sagan points out how in 'total institutions' like a military command, the strong organisational control over members can "encourage excessive loyalty and secrecy, disdain for outside expertise, and in some cases even cover-ups of safety problems, in order to protect the reputation of the institution."[9]

Normal accident theory does not provide a quantitative estimate of the probability of any given accident. This should not be taken as a deficiency of the theory. Broadly speaking there are two traditional ways of generating numerical probabilities of failures of systems. The first is to look at the history of operations of these systems and the number of failures during this period. This might work when the statistics of the system and its failures are sufficiently large, as for example when dealing with automobile accidents around the world. But this assumption does not hold for nuclear weapons and their associated systems. The second method, sometimes called the Fault Tree method, is to look at failure rates of individual components and use them to compute the probability of failure of the composite system. Normal accident theory undercuts this method by highlighting the unexpected and unquantifiable pathways that translate failure of small components of a complex system to a failure of the whole.

Due to its emphasis on both the technology and the politics of interactions within and between organisations, normal accident theory offers a more faithful and troubling understanding of how nuclear weapons are handled in the real world. This is in contrast to the perfectly operating machines and robot-like humans assumed by standard theories of nuclear deterrence.[10] Therefore we have no choice but to take the possibility of accidents seriously. We look now at some of the kinds of accidents that could happen in south Asia and their possible consequences.

Command and Control Issues

The problem of managing nuclear weapons in the real world poses unprecedented challenges.[11] As one description has vividly laid out, managing nuclear weapons "involves the unpredictability of circumstances and human behaviour interacting with complex sensors, communications systems, command centres and weapons. The smallest details can assume central importance and range widely in substance, from the legitimacy of presidential succession to computer algorithms, from the psychology of stress to the physics of electromagnetic pulse…Even the most advanced experts and the most experienced practitioners are narrowly and incompletely informed. No one understands the whole."[12]

Authority and Procedures

It is a normal requirement of every deployed military weapon that it should only be used when authorised by the appropriate authority and that the weapon will function as and when required (i e, it should be both reliable and safe). With nuclear weapons these demands become especially important since unlike ordinary weapons nuclear weapons have acquired an important diplomatic and political utility short of their use as an explosive. Only the highest political authorities are meant to be able to authorise the use of nuclear weapons. [There is however the possibility that the head of the state breaks down in a crisis. Political scientist Bruce

Russett mentions how "Richard Nixon, under the strains of his final days in the presidency, is said to have sobbed, beaten his fists on the floor of his office, and to have mused about his ability to release the forces of nuclear disaster. Defence secretary Schlesinger took special precautions to prevent unauthorised military acts or irrational orders."[13]]

Even the most intelligently designed system of command and control will not work unless the rules are carefully followed. An example of this was during the 1962 Cuban Missile Crisis at Malmstrom Air Force Base in Montana, US. An independent historical investigation suggested that during this crisis official safety rules were not implemented and personnel at the base had the ability to launch these missiles without authorisation.[14]

Moreover, there can be no manual containing minutely detailed procedures to cover all possible situations. As the US found for its SAGE warning and control system, "it was impossible to specify in advance all of the contingencies that could be faced in the course of actual operations. Reliance on formal written procedures proved impractical, and unwritten work-arounds soon developed among the human operators."[15] The larger lesson drawn in a study of this and other systems is that "any nuclear command organisation circumvents official procedures in order to carry out its assigned mission. Such rule short-cutting is likely to be oral and informal, and therefore invisible to outside observation except under the high-stress conditions of actual war or crisis".[16]

One of the problems during a war or a crisis stems from that the fact that the command and control authorities have not only to transmit their orders to military personnel on the field, i e, issue a *command*, but receive feedback on the situation on the field necessary for *control*. However, military forces may need to be covert to ensure their survival and therefore cannot transmit information for the fear that it would divulge their location. The contradiction deepens as the tempo of the battle increases, since information transmitted back would decrease, and the orders from higher authorities become increasingly divorced from the realities on the field.[17]

India's DND recommends that nuclear forces shall operate through "a combination of multiple redundant systems, mobility, dispersion and deception" for survivability. All of these create problems for effective and robust command and control. A different complication is introduced by the widespread, large-scale effects of nuclear war – these could disrupt communication systems that allow leaders or commanders to communicate with field personnel. It is an often overlooked fact that no nuclear command and control system has ever had to operate under the conditions in which it is intended to actually function, i e, during nuclear war. It is possible that fearing such worst-case circumstances, field commanders may be given the physical ability to launch nuclear weapons without authorisation by high-level political leaders.

False Alarms

The possession of a nuclear arsenal invites possible attacks by nuclear weapons of others. This has prompted nations to build systems to provide early warning of impending attack. The DND has posited a requirement for "effective intelligence and early warning capabilities"; it has also called for the creation of "space based and other assets" to "provide early warning, communications, damage/detonation assessment".

With these shall come the danger of false alarms and miscalculations. The history of the cold war between the US and the USSR abounds with examples. The US for instance had built an elaborate 'early warning system' which would warn them about impending missile attacks. The US early warning system was very sophisticated and used the latest state of the art technology involving a worldwide network of satellites and radars, with layers of filters to remove false signals. Yet, from 1977 through 1984, the only period for which official information has been released, the early warning systems gave an average of 2,598 warnings each year of potential incoming missiles attacks. Of these about 5 per cent required further evaluation.[18]

Information about the Russian experience is scarce, but there have been many false alarms there too. In 1995 for instance, a Norwegian scientific rocket launch was interpreted by the Russian early warning system as a possible attack and the matter went all the way up the command chain to president Yeltsin.[19]

Fortunately in each of these cases the mistake was discovered in time to forestall the ultimate counter-attack decision. Nevertheless, the shocking fact is that on many of these occasions, the world was just minutes away from a possible nuclear holocaust through error. With a missile flight time of 25-30 minutes from the US to Russia and vice versa, the time available to the US president for deciding how to respond was at most 15 minutes – which US officials admit would be available only "if every procedural and physical element in the whole warning and strategic command and control structure works perfectly".[20] An independent assessment of the same system suggests that there might only be about 10 minutes available to the US in which to make a decision, with an even tighter constraint on Russia.[21]

Technology and operating procedures combine at times to create major failures of early warning systems. A vivid example from the 1962 Cuban missile crisis involved an early warning radar that picked up what appeared to be a missile launch from Cuba against the US and reported it over the voice hotline to the command centre. Even after rechecking, the data was unambiguous. Since the missile was short range, there was nothing to do but wait for the detonation – which did not occur. It took a few minutes after that for analysts to realise that someone had inserted a software test tape at the same time as when the radar had detected a satellite, resulting in confusion.[22]

Early warning systems in India and Pakistan will, of course, also be prone to false alarms. The situation in south Asia is made more severe by geography. The missile travel time between Pakistan and India is only about 10 minutes – far too short a time to provide any meaningful warning or permit sensible decision-making. Bombs delivered by planes will take longer, but that is offset by the difficulty in spotting the bombers carrying nuclear weapons from the dozens of other similar planes in action during wartime. In light of these constraints, DND's call for setting up early warning systems must be balanced by a recognition that such a system would be more a source of last-minute false signals and confusion than timely and reliable information for effective decision-making.

These problems would be compounded during military crises. Amid the threats of attack, a dysfunctional early warning system will exacerbate the fear that nuclear attack is imminent, creating profound dilemmas for policy-makers. They may find themselves under immense pressure to prepare or launch a pre-emptive attack thereby compounding the crisis. Their alternatives might seem to be to use their nuclear weapons first or sit on their hands and wait for the bombs from the other sides to land. Under such circumstances declarations of No First Use may serve as no obstacle.

The dilemmas of command and control mentioned earlier become more acute with the installation of an early warning system that is inevitably prone to false alarms and create the risk of inadvertent launch through failure of technology. Nuclear weapons and missiles utilise a vast array of sensitive hi-tech components as do satellite-based detection systems and command and control structures. At a time of nuclear crisis, each of these systems has to work with total precision. A failure could lead to misinterpretation or miscalculation resulting in an inadvertent launch.

The US experience teaches us the valuable lesson that even a system using the most sophisticated technology in the world, made with the best available components and manned by a highly trained elite corps of the US military can fail time and again due to factors as mundane as human error and computer chip malfunction. We must add to this a realistic assessment of the state of technology and organisation in south Asia. One telling example is the report that prime minister Vajpayee cannot make a direct phone call from his aircraft since Air India One, a 20-year-old Boeing 737-200, doesn't have the facility.[23] No one familiar with the way infrastructural facilities function in India or Pakistan can fail to be concerned about our ability to maintain and run, day after day, such a vast and complex array of communication systems at a zero-error level. This is not due to inherent inability. After all, both countries have successfully completed many complex technological missions. However, there are important differences between something like a space launch and the maintenance of nuclear command and control systems. A failure in some component of a space launcher may lead to rescheduling, or at worst the loss of the rocket and satellite. Those are certainly very serious and expensive consequences, but nowhere as catastrophic as the possible consequences of a failure of some crucial communications link or a weapon safety mechanism.

Another difference is that a space launch or a nuclear test is an individual time-bound project climaxing in a particular event. It may be possible to maintain tight discipline for the duration of such special projects. However, nuclear weapons command, communication and launching systems are different in nature.[24] They are not going to be used on some pre-specified date, or periodically, from time to time. Hopefully they will remain unused for years together. Yet, in the event of a nuclear crisis the system will be called upon, within a matter of minutes, to function from end to end with full efficiency. Therefore, it will have to be maintained in perfect working order day after day at a zero margin of error in anticipation of a sudden crisis. Periodic checks and practice drills on individual links of the system are no substitutes for the real thing, when the entire system has to function amidst the chaos and tension of an impending nuclear attack. In the past, our proven record with the long-term maintenance of important but mostly dormant systems has not been so glorious. There is a tendency to start with great alertness and efficiency and then, as nothing untoward happens for a while, to let the vigilance slip.

Explosions Involving Nuclear Weapons

There is a family of risks associated with the storage and deployment of nuclear weapons, with the risk increasing with alert status.[25] These arise because deployed nuclear weapons are part of a system that includes the missiles or planes or other delivery systems into which they are integrated when they are operational, as well as the physical environment during their storage and transport. These are tightly coupled systems that can be prone to many kinds of accidents.

Of particular concern are accidents and fires involving the highly combustible fuels used in missiles and aircraft in the vicinity of nuclear weapons. Although tucked away inside a metal shell, a nuclear bomb is still vulnerable to being ignited by external fires and explosions. The most vulnerable element is the shell of powerful chemical high explosive (HE), which surrounds the core of either plutonium or highly enriched uranium in a typical nuclear fission weapon. (In fusion weapons, there is a second stage that is in turn ignited by the fission weapon described here.) The purpose of the HE is to crush the fissile material core into a critical mass and trigger a chain reaction, leading to the nuclear explosion.

There have been many accidents involving nuclear weapons. An official summary released by the US Department of Defence in 1981 lists 32 accidents involving US nuclear weapons between 1950 and 1980.[26] These accidents are typically caused by mishaps of delivery vehicles, either aircraft or missiles. Notable among missile accidents is the 1960 case of a US BOMARC missile at the McGuire Air Force base in New Jersey, which suffered an explosion, and a fire in the missile's fuel tanks.[27] There have also been accidents involving aircraft, the most famous being near Palomares, Spain, and Thule, Greenland. In both cases, aircraft carrying nuclear weapons crashed and the high explosive surrounding the nuclear core detonated, leading to the dispersal of plutonium over a large region.[28]

Information about accidents in the erstwhile Soviet Union is harder to obtain, but there are reports of at least 25 serious nuclear weapon accidents there.[29] These include a 1977 accident in which fuel leaked from a nuclear missile in its silo and subsequently exploded. Even as recently as June 16, 2000 a ballistic missile that was being unloaded near Vladivostok from a transport ship caught on the pier railing.[30] This led to a leak of approximately 3 tonnes of the oxidising agent, which in turn exploded. A number of people were injured and villages had to be evacuated. Fortunately in that instance the missile did not carry a nuclear warhead.

Liquid fuelled missiles, India's Prithvi and Pakistan's Ghauri, are of particular concern, especially during launch preparations. The Prithvi missile, for example, is fuelled by a liquid propellant consisting of an oxidiser of inhibited red fuming nitric acid (IRFNA) and a 50:50 mixture of xylidine and triethylamine.[31] This combination is hypergolic, i e, self-igniting and highly volatile and has to be loaded just prior to launch.

Solid fuel missiles carry their own hazards, associated with inadvertent ignition. This can be caused by a number of sources, including stray or induced electrical currents and electrostatic discharges; it is believed that a US Pershing missile was ignited while in its transporter erector vehicle by such effects.[32] Impacts, such as being struck by a bullet or being dropped on to a hard surface, and "excessive mechanical vibration, e g, prolonged bouncing during transport" can also trigger ignition.[33] The latter could be a particularly acute problem for road mobile solid fuelled missiles such as India's Agni and Pakistan's Shaheen if they were to be inducted into the armed forces and deployed into the field.

There have been no reports so far of accidents in south Asia involving long-range ballistic missiles, but there have been accidents at missile development and production facilities. A recent example was the fire at the High Explosive Materials Research Laboratory, Pune, belonging to the Defence Research and Development Organisation on April 25, 2002; the accident involved sensitive chemicals in the solid rocket propellant section of the laboratory and killed six people including four casual labourers.[34]

Even familiar military systems show a disturbing safety pattern in south Asia. India's Comptroller and Auditor General reported in 1997 that there had been 187 accidents and 2,729 incidents involving Indian Air Force (IAF) aircraft between April 1991 and March 1997, in which the IAF lost 147 aircraft and 63 pilots.[35] The Comptroller's report suggested 41 per cent of the losses were due to human error while 44 per cent were due to technical defects, and claimed, "The IAF attributed the accidents to technical defects due to deficient operation/maintenance procedure".[36] According to the Pakistan Institute for Air Defence Studies, there were 11 major Pakistan Air Force (PAF) accidents between January 1997 and August 1998 in which planes were lost.[37] There were at least another seven accidents involving airforce planes by April 2000. Accidents involving Pakistani military jets have included crashes into heavily populated areas. In July 1998 a PAF jet from PAF Masroor crashed into a residential area in Karachi, killing six people and injuring at least 25.[38]

There have also been many major fires in large ammunition depots. In April 2000, a fire at the Bharatpur field ammunition depot destroyed around 12,000 tonnes of ammunition, including surface-to-air missiles, anti-tank guided missiles, tank and artillery shells.[39] There were other similar fires at Birdhwal Head and at Bikaner. In April 1988, the Ojhri ammunition depot located close to the twin cities of Islamabad and Rawalpindi exploded; the official toll was about a hundred people killed and a thousand injured.[40] Other tallies suggested that between 6,000 and 7,000 people were killed and many thousands injured.[41] If Prithvi or Ghauri missiles loaded with nuclear weapons happened to be in a depot during one such fire, the type of accidents we are concerned about can easily happen.

Once the HE inside a nuclear weapon catches fire due to some external accident or fire it could result in one of three possibilities, listed below in increasing order of seriousness:

(i) the High Explosive burns *but does not detonate*;

(ii) the HE *detonates* leading to vaporisation of the plutonium and its dispersal into the atmosphere;

(iii) The HE detonates triggering an uncontrolled fission reaction and a *nuclear explosion.*

In the first scenario, the burning of the HE will lead to the melting of the weapon and could release a limited amount of plutonium into the environment. But this will be localised in the immediate vicinity of the accident and limit the severity of its effect on the environment and public health. So we will not elaborate on this possibility any further.

Let us now consider the second scenario. Even if the detonation of the HE does not result in a full-scale nuclear explosion, it can convert all of the plutonium into a fine aerosol.[42] This aerosol will rise with the hot gases created by the explosion, mix with the air and spread. Any prevailing wind would transport it to considerable distances, typically up to tens of kilometres. People and animals in this region would inhale this plutonium-laden atmosphere.

The biological damage caused by plutonium exposure is a complicated matter, but it has been studied extensively. The two primary routes of damage by plutonium contamination are ingestion and inhalation. Ingestion of plutonium is a less significant risk since almost all of the plutonium is excreted within a few days.[43] The more serious risk comes from inhalation of very small plutonium particles, which can stay imbedded deep in the lungs typically for periods of the order of a year, leading to increased rates of lung, liver and bone cancers. Even at arbitrarily low concentrations inhalation of this plutonium poses a non-zero cancer hazard. Consequently there is a substantial cumulative contribution to cancer fatalities even from areas faraway from the site of the accident.

Imagine a nuclear weapons accident of this type at an air force base or nuclear weapons depot, which happens to be at the edge of a major city in our subcontinent. If the city happens to be downwind at the time of the explosion then our calculations show that there could be approximately 5,000-20,000 cancer deaths from the resulting plutonium inhalation.[44] While less devastating than a full-scale nuclear explosion, this is still a huge tragedy. Even the lower estimate of this casualty count is larger than the total number of fatalities in the September 11 attack on New York's World Trade Centre that shook the world.

The risk of such an accident is not far-fetched. There *are* bases and cantonments at the edges of large cities and there is no publicly available information that assures us that a nuclear weapon will not be stored in one of these or transit though them.

Even if such an accident did not take place at the edge of a major metropolis but happened, say, 50 kilometres upwind of a middle-sized town the resulting toll would still be considerable. Our estimates show that it would lead to approximately 200-900 fatalities from the town and the surrounding countryside. In all these cases, in addition to the fatalities there will be the medical costs of treating the fatal and non-fatal cancers resulting from inhalation of plutonium. To this human cost has to be added the massive financial cost of even limited decontamination of just the immediate neighbourhood of the accident, which could be hundreds of crores of rupees.[45]

Accidental Nuclear Detonation

The estimate of casualties and damage described above is not for a nuclear explosion, but only for the detonation of the high explosive in the weapon. The detonation of the high explosive surrounding a nuclear core could trigger in turn a nuclear explosion. This possibility has prompted the US and Russia to build in safety features into the design of their weapons. For instance, modern nuclear weapons in the US arsenal are said to be 'one-point safe', i e, their design ensures that the accidental explosion of just one of the HE packages will not trigger a *nuclear* explosion.[46] However, considerable testing has to be done before installing such safety measures into weapon design. The US is estimated to have carried out about 130 very low yield safety related tests, of which 62 are officially acknowledged as one-point safety tests.[47] The USSR reportedly conducted about 25 safety tests between 1949 and 1990.[48]

It is in the face of this history that we have to assess nuclear weapons safety in the subcontinent. Given that officially there have been only two sets of tests by India and one by Pakistan, it is quite possible that their nuclear weapons may not incorporate such design-level safety. It is therefore reasonable to be concerned about the possibility of accidents triggering nuclear explosions. Should such an accident take place, the nuclear yield could be as large as the design yield of the nuclear bomb or warhead.

An accidental nuclear explosion with a yield of 15 kilotons, the same as the weapon detonated over Hiroshima, would destroy over 5 square kilometres from the combined effects of blast damage and firestorms. Over 24 square kilometres would be subject to radioactive fallout at levels such that half the adult, healthy population would die from radiation sickness. If this were to happen in the vicinity of a large south Asian city, several hundreds of thousands of people would die.[49] In addition, such an explosion, especially in times of crises, might be assumed to be a nuclear attack and lead to a nuclear response. Thus an accidental nuclear explosion may even initiate a nuclear war. Table below shows (to the nearest thousand) the numbers of dead, severely injured and slightly injured persons after a nuclear attack on each of ten large south Asian cities. A total of 2.9 million deaths is predicted for these cities in India and Pakistan with an additional 1.5 million severely injured.

Reducing Risk

From all that we know publicly, India and Pakistan are yet to routinely deploy their missiles with nuclear warheads. But as we pointed out in the beginning of the paper, the Indian Draft Nuclear Doctrine calls for the ability to shift to "fully employable forces *in the shortest possible time*". A missile regiment to handle the nuclear-capable Agni missile is being raised.[51] Military officers are being trained to handle nuclear weapons.[52] There have been statements by senior officials about Agni being mated with nuclear warheads.[53] All of this is consistent with eventual deployment. Pakistan will likely find its own path to the same point. With deployment come increased risks of the many dangers we have outlined.

It is therefore appropriate to think of risk reduction measures. Since the Indian and Pakistani nuclear arsenals are still in the early stages, with nuclear strategies still not firmly in place, there may yet be time to influence policy-makers into incorporating some of the following risk reduction measures. Once the nuclear arsenals are fully developed with constituencies in the armed forces and government bureaucracies, changing operational practices would be strongly opposed by these institutional interests. Despite the end of the cold war and the collapse of the Soviet Union, the inability of the US and Russia to significantly decrease their reliance on nuclear weapons is proof of the power of such institutional interests.[54]

Non-Deployment and Non-Mating

Deployment of nuclear armed missiles and bombers decreases the time available to political leaders to evaluate signals of impending attack and deliberate, possibly in conjunction with leaders of other countries, before responding. It also tempts them to use nuclear weapons as means of coercive diplomacy.[55] Both of these concerns are made more acute if weapons and delivery systems are kept on alert status.

The first step to address these concerns in India and Pakistan is to maintain the current status of non-deployment. This both increases the decision-making time and makes it more difficult to rattle nuclear sabres, thus reducing the risk of accidental or inadvertent use of nuclear weapons. There will then be little or no incentive for relying on early warning and fewer demands on command and control. Safety would be enhanced if the weapons themselves were not mated to delivery systems, as is reported to be the case so far in India.[56] But it must be ensured that this situation is not just a feature of the early stages of nuclear armament and will be a matter of policy as long as nuclear weapons are around.

In November 1998, India introduced a resolution at the General Assembly of the UN calling for immediate and urgent steps to reduce the risks of unintentional and accidental use of nuclear weapons through de-alerting.[57] The term de-alerting arose in the context of the US and Russia and refers to deliberately standing down one's nuclear arsenal from a state of heightened readiness by introducing built-in delays. Arms control analysts have discussed at length various de-alerting scenarios for the US and Russia.[58] Some de-alerting (though far from full) had actually been done by the US around 1991 when Minuteman missiles (slated for later elimination under the START 1 agreement) were ordered to stand down.

In the case of the US and Russia, there have been suggestions to strengthen the de-alert status of the missiles by building in further delays in loading the weapons through measures such as removing the gas generators that open the heavy silo lids before missile launch or replacing the missiles' aerodynamic shrouds (nose cones) by non-aerodynamic covers that prevent normal missile flight.[59] Other de-alert measures proposed have included removal of guidance systems from submarine launched ballistic missiles and storing them separately, and redirecting US nuclear submarines to patrol deep in the southern hemisphere out of immediate range of their targets in Russia.

In the case of south Asia, non-deployment and demating are simple, robust and inexpensive forms of de-alerting. They require no new technologies or organisation and simply take advantage of the fact that neither India nor Pakistan have driven themselves to the very large continuously deployed hyper-alert nuclear forces of the superpowers. These measures ensure that it would take anywhere from a few hours to a day before a launch can be executed after orders are given. Such an in-built time-gap between the decision to fire and its execution will reduce many of the risks listed earlier.

The pressure to launch a pre-emptive attack would be all the more intense if missiles and bombers loaded with nuclear weapons were already fully deployed and ready to take off in minutes. When such firepower is kept primed day after day, ready to be used any moment, it is itching to be fired. The mere availability of such capability generates a momentum of its own to the decision-making process. Further, should there be a perception of military imbalance or advantage accruing to the one who strikes first, this pressure would be enhanced.

Another benefit of storing the weapons separately from the missiles and bombers is that the chances of explosions involving nuclear weapons described earlier would be greatly reduced. This safety can be further augmented by keeping the weap-

Table: Estimated Nuclear Casualties[50]

City	Killed	Severely Injured
India		
Bangalore	3,14,000	1,75,000
Bombay	4,77,000	2,29,000
Calcutta	3,57,000	1,98,000
Madras	3,64,000	1,96,000
New Delhi	1,76,000	94,000
Pakistan		
Faisalabad	3,36,000	1,74,000
Islamabad	1,54,000	67,000
Karachi	2,40,000	1,27,000
Lahore	2,58,000	1,50,000
Rawalpindi	1,84,000	97,000

ons themselves disassembled with the fissile core separated from the chemical high explosive. This would preclude the need to use, as the US does, 'Insensitive High Explosives', which cannot be set off so easily, or using 'Fire Resistant Pits', that are less susceptible to fires.

Permissive Action Links

A safety measure widely used in the US against accidental or unauthorised launch of nuclear weapons is the installation of Permissive Action Link (PAL). PALs are electronic switches that serve to protect a nuclear weapon against unauthorised use, and are meant to be effective even when the weapon is assembled and mated to its delivery system. Recent PALs use a set of multiple, six digit or 12 digit codes with a limited try capability. Since these are electronic locks, the limited try capability stops any effort to keep trying codes until the correct one is determined.[60]

The Soviet Union seemed to have been sceptical about relying on the technical effectiveness of coded locks for its nuclear weapons, especially bombs to be used by aircraft. It chose to store its bombs in depots a kilometre or two from the airbases with its strategic bombers and placed the depots under the custody of special troops commanded by the senior general staff.[61] The nuclear weapons were kept away from the bombers during normal operations. There were additional safety measures for when the bombers were armed and in flight, including special on-board navigation equipment to assure the aircraft's flight pattern conformed to preplanned operations before the bomb could be released.

Both India and Pakistan have hinted about their need for PAL systems. Whether PALs are introduced into south Asia or not, it is important to appreciate that they are not without problems. At first sight, by limiting unauthorised access to nuclear weapons PALs may seem as contributing to reducing possible dangers. However, the matter is more complex. The prospect of tight, assured control over nuclear forces that PALs appear to offer may tempt political leaders and military planners to deploy their nuclear forces and use these as instruments of diplomacy. This was in fact an early argument for PALs and brinkmanship; Fred Ikle, described as the 'father' of PALs, advocated in the late 1950s that such devices "could permit substantial gains in readiness by replacing more time-consuming operational safeguards and by making higher alert postures politically acceptable".[62] Control through technology rather than relying on people is presented as making risks seem less daring and thus easier to rationalise.

This temptation may be particularly great in south Asia where both India and Pakistan believe that in a crisis the US would use spy planes, satellites and electronic signals intelligence to closely monitor events, and may be incited into intervening. In the past, Pakistan, in particular, has sought to elicit such intervention through readying their nuclear weapons for deployment, most notably in the Kargil conflict of 1999. It is easy to imagine how in a crisis a perceived increase of control may lead to a greater willingness among Pakistani policy-makers to pursue this strategy further.

Conclusion

The only sure way to eliminate these nuclear risks is to abolish all nuclear weapons, regionally and globally. This should continue to be the ultimate goal of all rational and peace loving people. But as of now, nuclear weapons *are* here. Even as we strive to eliminate them altogether, it would in the meantime be prudent to press for various risk reduction measures, that could make the chances of a destructive nuclear war lower. But no level of risk is acceptable enough to justify living with nuclear weapons. As long as the nuclear weapons are there, there will be a risk of use of nuclear weapons and hence these measures should only be considered as transitional elements en route to nuclear disarmament.

Nuclear weapons and the systems for their control, delivery and use are enormously complicated systems. Our discussion of the theory of normal accidents strongly suggests that catastrophic accidents would be inevitable in such systems. By their very nature, bureaucracies controlling and operating nuclear weapons tend to underestimate the possibility of such accidents and not take adequate precautions.

The primary risk reduction measure we have suggested is that India and Pakistan not deploy, as a matter of formal policy, nuclear armed missiles and aircraft. These steps require no new technologies or organisations – indeed not deploying would reduce enormously the demands for early warning technologies or complicated command and control structures. Safety could be further augmented by keeping nuclear weapons disassembled with the nuclear cores separated from the chemical high explosive systems.

While India and Pakistan are yet to deploy their weapons on a permanent operational basis, there are many sources of pressure driving the two countries towards that posture. It is imperative that these pressures be resisted now, before these weapons are actually deployed. The lives of more than a billion people are at stake. EPW

Notes

1 Bruce Riedel, *American Diplomacy and the 1999 Kargil Summit at Blair House*, Centre for the Advance Study of India Policy Paper, University of Pennsylvania, 2002. Available on the internet at http://www.sas.upenn.edu/casi/reports/RiedelPaper051302.htm While disturbing in itself, what is even more disturbing is that during the meeting between prime minister Nawaz Sharif and president Bill Clinton, Sharif seemed 'taken aback' when confronted with this fact.

2 Raj Chengappa, *Weapons of Peace: The Secret Story of India's Quest to be a Nuclear Power*, Harper Collins, New Delhi, 2000, p 437.

3 Mayed Ali, 'Tactical N-Warheads Moved along Borders', *The News*, May 28, 2002; 'Yes, Pakistan Has Tactical Nukes: Interview with Lt Gen D B Shekatkar', *Outlook*, June 10, 2002.

4 'Draft Report of National Security Advisory Board on Indian Nuclear Doctrine', Available on the internet at http://www.indianembassy.org/policy/CTBT/nuclear_doctrine_aug_17_1999.html

5 The contradictions in the notion of a credible minimum nuclear deterrent are elaborated in M V Ramana, 'A Recipe for Disaster', *The Hindu*, September 9, 1999. For broader critiques of the notion of deterrence, especially within a south Asian context, see Praful Bidwai and Achin Vanaik, *South Asia on a Short Fuse: Nuclear Politics and the Future of Global Disarmament*, Oxford University Press, New Delhi, 1999.

6 Charles Perrow, *Normal Accidents: Living with High-Risk Technologies*, Basic Books, New York, 1984.

7 Diane Vaughan, *The Challenger Launch Decision: Risky Technology, Culture, and Deviance at NASA*, University of Chicago Press, Chicago, 1996, p 394.

8 Scott Sagan, *The Limits of Safety*, Princeton University Press, Princeton, 1993.

9 Scott Sagan, *The Limits of Safety*, p 254.

10 On the artificial world of nuclear war planners, see Carol Cohn, 'Sex and Death in the Rational World of Defence Intellectuals', *Signs: Journal of Women in Culture and Society* 12, no 9 (1987).

11 This discussion draws upon a forthcoming essay by Zia Mian, 'A Nuclear Tiger by the

Tail: Some Problems of Command and Control in South Asia', to appear in M V Ramana, and C Rammanohar Reddy (eds), *Prisoners of the Nuclear Dream*, Orient Longman, New Delhi, 2002.

12 Ashton B Carter, John D Steinbruner, Charles Z Zraket, 'Introduction' in Ashton B Carter, John D Steinbruner, Charles Z Zraket (eds), *Managing Nuclear Operations*, The Brookings Institution, Washington, 1987, pp 1-13, p 3.

13 Bruce Russett, *The Prisoners of Insecurity: Nuclear Deterrence, The Arms Race, and Arms Control*, W H Freeman and Company, San Francisco, 1983, pp 120-21.

14 Scott Sagan, *The Limits of Safety*, pp 81-90.

15 Paul Bracken, *The Command and Control of Nuclear Forces*, Yale University Press, New Haven, 1983, p 12.

16 Paul Bracken, *The Command and Control of Nuclear Forces*, pp 12-13.

17 Bruce Blair, 'Alerting in Crisis and Conventional War' in *Managing Nuclear Operations*, pp 75-120, p 117.

18 Bruce Blair, *The Logic Of Accidental Nuclear War*, Brookings Institution Press, Washington, DC, 1993, fn 46, pp 342-43. Also see H L Abrams, 'Strategic Defense and Inadvertent Nuclear War' in H Wiberg, I D Petersen and P Smoker (eds), *Inadvertent Nuclear War: The Implications of the Changing Global Order*, Pergamon Press, Oxford, 1993, pp 39-55.

19 Bruce G Blair, Harold A Feiveson and Frank von Hippel, 'Taking Nuclear Weapons off Hair-Trigger Alert', *Scientific American*, November 1997.

20 Weapons Systems Evaluation Group Report 50, Enclosure C, September 1960, cited in Bruce Blair, John Pike, and Stephen Schwartz, 'Targeting and Controlling the Bomb' in Stephen Schwartz (ed), *Atomic Audit*, Brookings Institution Press, Washington, DC, 1998, pp 197-268, p 207.

21 Bruce Blair, *The Logic of Accidental Nuclear War*, pp 188-91.

22 Scott Sagan, *The Limits of Safety*, pp 130-31.

23 Bhavna Vij, 'Minor Embarrassment: Vajpayee Cannot Dial Direct from His Aircraft', *Indian Express*, November 7, 2001.

24 See for example Lloyd Dumas, 'Why Mistakes Happen Even When the Stakes are High: The Many Dimensions of Human Fallibility', *Medicine and Global Survival* 7, No 1, April 2001, pp 12-19.

25 This is discussed in much greater technical detail in Zia Mian, M V Ramana and R Rajaraman, 'Plutonium Dispersal and Health Hazards from Nuclear Weapon Accidents', *Current Science* 80, No 10, May 25, 2001, pp 1275-84.

26 US Department of Defense in coordination with Department of Energy, *Narrative Summaries of Accidents Involving US Nuclear Weapons, 1950-1980 (Interim)*, 1981.

27 Jaya Tiwari and Cleve J Gray, 'US Nuclear Weapons Accidents', available on the internet at: http://www.cdi.org/Issues/NukeAccidents/accidents.htm

28 In the case of Palomares, several square kilometres were contaminated with high plutonium ground concentrations. E Iranzo, S Salvador and C E Iranzo, 'Air Concentrations of 239Pu and 240Pu and Potential Radiation Doses to Persons Living near Pu-contaminated Areas in Palomares, Spain', *Health Physics* 52, No 4, April 1987, pp 453-61.

29 Shaun Gregory, *The Hidden Cost of Deterrence: Nuclear Weapons Accidents*, Brassey's, London, 1990, pp 184-90.

30 British Broadcasting Corporation, 'Toxic Cloud Moves Along Russian Far Eastern Coast After Missile Fuel Leak', June 16, 2000

31 For details on the Prithvi and its operational practices see Zia Mian, A H Nayyar and M V Ramana, 'Bringing Prithvi Down to Earth: The Capabilities and Potential Effectiveness of India's Prithvi Missile', *Science and Global Security* 7, No 3, 1998, pp 333-60.

32 George P Sutton, *Rocket Propellant Elements: An Introduction to the Engineering of Rockets*, 6th Edition, John Wiley, New York, 1992, p 427.

33 George P Sutton, *Rocket Propellant Elements*, pp 400, 427.

34 'Six Die in DRDO Lab Fire in Pune', *The Times of India*, April 26, 2002.

35 Report of the Comptroller and Auditor General of India on the Ministry of Defence for the year ending March 1997, http://www.cagindia.org/reports/defence/1998_book1/index.htm

36 Report of the Comptroller and Auditor General of India on the Ministry of Defence for the year ending March 1997, http://www.cagindia.org/reports/defence/1998_book1/index.htm

37 Attrition Statistics, Pakistan Institute for Air Defence Studies, http://www.piads.com.pk/users/piads/attritionpaf.html

38 Ghulam Hasnain, 'Air Force Plane Crashes into Pakistani Neighbourhood', Associated Press, July 30, 1998.

39 'War Reserves Worth Several Hundred Crores Wiped Out', *The Times of India*, April 30, 2000.

40 '80 Killed, 1000 Injured: Army Ammunition Dump Blows Up in Pindi', *Dawn*, April 11, 1998.

41 'MRD Convenor Seeks Judicial Probe Into Ojhri Blasts', *Dawn*, April 21, 1988.

42 We will focus on such accidents involving plutonium. India has used plutonium in its nuclear weapons. Though Pakistan has so far relied on uranium, with production of plutonium from the Khushab reactor starting, Pakistan may follow India in developing plutonium based weapons as well.

43 The International Commission on Radiological Protection estimates that only 0.05 per cent of ingested plutonium is absorbed by the gastrointestinal system. ICRP, *Age-dependent Doses to Members of the Public from Intake of Radionuclides: Part 2 Ingestion Dose Coefficients*, ICRP Publication 67, Pergamon, New York, 1994, p 127.

44 Zia Mian, M V Ramana and R Rajaraman, 'Plutonium Dispersal and Health Hazards from Nuclear Weapon Accidents'.

45 David Chanin and Walter Murfin, 'Site Restoration: Estimation of Attributable Costs From Plutonium-Dispersal Accidents', Sandia National Laboratory Report, SAND96-0957, May 1996, Available on the internet at http://plutonium-erl.actx.edu/restoration.html

46 The formal US definition of one point safety requires that the nuclear weapon design inherently, i e, without any external devices, have a probability of less than one in a million of producing a nuclear yield greater than four pounds of TNT equivalent in the event of a detonation at any one point in the HE system. Sidney Drell and Bob Peurifoy, 'Technical Issues of a Nuclear Test Ban', *Annual Reviews of Nuclear and Particle Science* 44 (1994), pp 285-327. For comparison, the weapon that exploded over Hiroshima in 1945 had a yield of about 13,000 tonnes of TNT equivalent.

47 Thomas B Cochran and Christopher E Paine, 'Hydronuclear Testing and the Comprehensive Test Ban: Memorandum to Participants JASON 1994 Summer Study', Natural Resources Defense Council, Washington, DC, 1994, p 11.

48 Robert S Norris and William Arkin, 'Soviet Nuclear Testing, August 29, 1949-October 24, 1990', *The Bulletin of the Atomic Scientists*, May/June 1998.

49 M V Ramana, *Bombing Bombay: Effects of Nuclear Weapons and a Case Study of a Hypothetical Explosion*, International Physicians for the Prevention of Nuclear War, Cambridge, 1999, p 31.

50 Matthew McKinzie, Zia Mian, A H Nayyar and M V Ramana, 'The Risks and Consequences of Nuclear War in South Asia' in Smitu Kothari and Zia Mian (eds), *Out of the Nuclear Shadow*, Lokayan and Rainbow Publishers, New Delhi and Zed Books, London, 2001, pp 185-96.

51 'Agni Missile Group for Army Cleared', *The Hindu*, 16 May 2002.

52 Vishal Thapar, 'Navy, IAF Train in Handling Nukes', *The Hindustan Times*, February 15, 2002.

53 Some of these are listed in M V Ramana, 'A Nuclear Wedge', *Frontline*, December 8, 2001.

54 For an analysis of failed attempts at post-cold war restructuring of US nuclear arsenals see Janne Nolan, *An Elusive Consensus: Nuclear Weapons and American Security After the Cold War*, Brookings Institution Press, Washington, DC, 1999.

55 Richard K Betts, *Nuclear Blackmail and Nuclear Balance*, Brookings Institution, Washington, DC, 1987.

56 Manoj Joshi, 'Our Nukes Have Safety Locks', *The Times of India*, November 4, 2001.

57 Rebecca Johnson, 'First Committee Report', *Disarmament Diplomacy*, No 32, November 1998, available on the web at http://www.acronym.org.uk/dd/dd32/32first.htm; Also see 'India Moves Resolution on De-alerting N-forces,' *Rediff on the Net*, November 3, 1998.

58 See for example the discussion in Harold Feiveson (ed), *The Nuclear Turning Point: A Blueprint for Deep Cuts and De-Alerting of Nuclear Weapons*, Brookings Institution Press, Washington, DC, 1999.

59 Bruce Blair, Harold Feiveson and Frank von Hippel, 'De-Alerting Russian and American Nuclear Missiles', *UNIDIR NewsLetter*, No 38, 1998, pp 19-22.

60 See Peter Stein and Peter Feaver, *Assuring Control of Nuclear Weapons*, CSIA Occasional Paper No 2, Centre for Science and International Affairs, Harvard University, 1987.

61 Bruce G Blair, *Global Zero Alert for Nuclear Forces*, Brookings Occasional Papers, The Brooking Institution, Washington, 1995.

62 Peter Stein and Peter Feaver, *Assuring Control of Nuclear Weapons*, p 24.