VULNERABILITY OF RESEARCH REACTORS TO ATTACK

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RESEARCH FELLOW FINAL REPORT

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EXECUTIVE SUMMARY

After 9/11, countries around the world are re-evaluating the safety and security of their nuclear facilities against sabotage acts. An act of nuclear terrorism on research reactors is of very remote probability in Pakistan, since the controls and security measures around various nuclear installations and radiation facilities in Pakistan are enough to deter and delay a terrorist attack and any such attempt would be detected in the early stages. Moreover, the sabotage act on nuclear installation is not very attractive to a terrorist group in general and specifically within the context of Pakistan. Nevertheless, the paper aims to provide information about the evolution of research reactors, barriers available for their protection, various modes of nuclear terrorism, and physical protection measures required to reduce the probability of terrorist acts. In addition, Pakistan's response to nuclear terrorism and improvements needed to manage such emergencies (if they happen) are discussed in this paper.

INTRODUCTION

Humanity's entrance into the twenty-first century is significantly clouded by the danger of terrorism. Each year, thousands of people around the world fall victim to terrorist acts. The methods used by terrorists are becoming ever more diversified and refined. With the increasing number of terrorist and extremist groups, these groups are getting better equipped technically. The threat of "terrorism of mass destruction" is becoming ever more realistic. Terrorism knows no boundaries. The problem is international, but the effects are felt locally.[1] The terrorist attacks of September 2001 have given official credibility to the use of wide-body civilian aircraft as weapons, however, no nuclear facility has been specifically designed to withstand such an attack.[2] In these circumstances, the danger of terrorism against nuclear facilities cannot be overlooked. On the basis of their analysis of the security status of research reactors and the possible nature of terrorist threats, the US scientists warn: The most dangerous consequences could take place in attacks on reactors of medium (1-10 MW) and large (10-250 MW) capacity. Here there is a significant quantity of radioactive materials, and, in addition, they are more weakly protected against outside attack than nuclear power reactors.[3]

There is no treaty requiring any level of protection for power or research reactors from terrorists. IAEA Information Circular 225 contains no specific recommendations on how to guard against sabotage of research reactors. National statutes and regulations on physical protection of reactors vary a great deal around the world. Differences in culture, perceived threat, financial and technical resources and national laws are some of the reasons.[4] Most research reactors lack adequate exclusion zones to guard against the potential for truck bombs and perimeter protection. "Typically a wire fence without anti vehicle barriers, motion sensors, or electronic/computer based detection and assessment systems is what one finds at nuclear power plants". In addition, many research reactors are located on university campuses, where security tends to be less rigorous than at commercial reactor sites and they also have no containment structure.[5]

Today, the danger of a terrorist attack at a nuclear power plant in the United States --- either from the air or from the ground --- is apparently as great as ever. According to a January 14, 2004 speech by Robert L. Hutchings, Chairman of the National Intelligence Council (NIC),

> "Targets such as nuclear power plants … are high on al Qa'ida's targeting list as a way to sow panic and hurt our economy … The group has continued to hone its use of transportation assets as weapons … although we have disrupted several airline plots, we have not eliminated the threat to airplanes. There are still al Qa'ida operatives who we believe have been deployed

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[1] High-Impact Terrorism, Proceedings of a Russian–American Workshop, National Academy Press, Washington, D.C.; [http://www.nap.edu].

[2] International Union, Security, Police and Fire Professionals of America, (SPFPA), SPFPA Index Page; [http://www.spfpa. org/nucleardivision.html]

[3] Russian Commentary Examines Risks of Terrorist Attacks on Research Reactors; [http://www.sgpproject.org/Personal%20Use%20Only/RUBelous.html].

[4] George Bunn, Chaim Braun; Terrorism Potential for Research Reactors Compared with Power Reactors; Center for International security and cooperation, Stanford University.

[5] Charles D. Ferguso; The Four Faces of Nuclear Terrorism; Center for Nonproliferation Studies, 460, Pierce Street, Monterey, California, USA.

> to hijack planes and fly them into key targets … al Qa'ida's intent is clear. Its capabilities are circumscribed but still substantial. And our vulnerabilities are still great."[6]

For almost 60 years, research reactors have been centers of innovation and productivity for nuclear science and technology. The multi-disciplinary research that research reactors support has spawned new developments in nuclear power, radioisotope production, neutron beam research, nuclear medicine, materials development, component testing, computer code validation and pollution control.[7] It is important to keep them safe from both accident and sabotage, not only because of our obligation to prevent human and environmental consequences but also to prevent corresponding damage to science and industry.[8]

Presently, two nuclear power plants are in operation that generate 437 MWe. One reactor having capacity of 300 MWe is under constru[1]ction. In addition, there are two research reactors having power of 10 MW and 27 KW. They are used mainly for research studies in physics, isotope production, and for training engineers, scientists, and technicians. Given the above considerations, the present paper briefly reviews Pakistan's vulnerability to nuclear terrorism on research reactors.

EVOLUTION OF RESEARCH REACTORS: A BRIEF HISTORY

United States of America

It is human nature to test, observe, and dream. This history of nuclear energy is the story of a centuries-old dream becoming a reality.

Ancient Greek philosophers first developed the idea that all matter is composed of invisible particles called atoms. The word atom comes from the Greek word, atomos, meaning indivisible. Scientists in the 18th and 19th centuries revised the concept based on their experiments. The physicists Henri Bequerel, Willhelm Roentgen, Ernest Rutherford, Niels Bohr, Pierre and Marie Curie, and J.J. Thompson contributed to the rise of nuclear physics through a series of discoveries concerning radioactivity, atomic structure, and the behavior of Protons, Neutrons and Electrons that make up the Atom. They made this invisible world visible. A number of the pioneers in the study of radioactivity themselves became sick or died from the effects of the invisible action of radiation on their bodies. In 1932, the so-called "the miraculous year" (Annus Mirabilus), James Chadwick discovered the neutron by bombarding elements with alpha particles, Carl David Anderson discovered the positron, and John Cockcroft and Ernest Walton produced the first artificial disintegration of the atomic nucleus. These discoveries triggered international investigation of the nucleus. Enrico Fermi in Rome, Kirill Sinelnikov and Alexandr Leipunski in Kharkiv, contributed to this basic research. Fermi induced artificial radioactivity in the laboratory, leading to the formation of transuranic elements. In 1938 Otto Hahn and Lise Meitner (assisted by Fritz Strassman) discovered fission: they determined that when uranium split it formed two lighter elements and gave off neutrons.[9]

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[6] *Chernobyl on the Hudson? [www.secureindianpoint.org/downloads/IPhealthstudy.pdf].*

[7] IAEA Division of Physical and Chemical Sciences, Research Reactors Purpose and Future Brochure; [http://www-naweb.iaea.org/napc/physics/ACTIVITIES/Foreword.htm].

[8] David Huizenga, Douglas Newton, Joyce Connery;Improving Nuclear Safety at International Research Reactors: The Integrated Research Reactor Safety Enhancement Program (IRRSEP); Office of International Nuclear Safety and Cooperation, National Nuclear Security Administration, U.S. Department of Energy; [http://www.rertr.anl.gov/Web2002/2003Web/Huizenga.html].

[9] Open Society Archive; [http://www.osa.ceu.hu/guide/rip/10/TheExhibitionI.html]

In 1939, Neil Bohr came to America and shared with Einstein the Hahn-Strassman-Meitner discoveries. Bohr also discussed with Fermi the exciting possibility of a self-sustaining chain reaction. Scientists throughout the world began to believe that a self-sustaining chain reaction might be possible. It would happen if enough uranium could be brought together under proper conditions. The amount of uranium needed to make a self-sustaining chain reaction is called a critical mass. Fermi and his associate, Leo Szilard, suggested a possible design for a uranium chain reactor in 1941. Their model consisted of uranium placed in a stack of graphite to make a cube-like frame of fissionable material. Early in 1942, a group of scientists led by Fermi gathered at the University of Chicago to develop their theories. By November 1942, they were ready for construction to begin on the world's first nuclear reactor, which became known as Chicago Pile-1. The pile was erected on the floor of a squash court beneath the University of Chicago's athletic stadium. In addition to uranium and graphite, it contained control rods made of cadmium. Cadmium is a metallic element that absorbs neutrons. When the rods were in the pile, there were fewer neutrons to fission uranium atoms. This slowed the chain reaction. When the rods were pulled out, more neutrons were available to split atoms. The chain reaction sped up.

On the morning of December 2, 1942, the scientists were ready to begin a demonstration of Chicago Pile-1. Fermi ordered the control rods to be withdrawn a few inches at a time during the next several hours. Finally, at 3:25 p.m., Chicago time, the nuclear reaction became self-sustaining. Fermi and his group had successfully transformed scientific theory into technological reality. The world had entered the nuclear age.[10]

Union of Soviet Socialist Republics (Russia)

In parallel to the United States, Russian scientists also took active part for the development of nuclear energy. The commencement of the experimental investigations into the structure of the atomic nucleus began in 1937 by the production of the first proton beam and of “pulse” amounts of neptunium and plutonium in the Leningrad Radium Institute using the first cyclotron in Europe. Atomic research proceeded until in 1946 and a controlled uranium fission chain reaction was achieved for the first time in Europe and Asia using the first experimental uranium-graphite reactor in Kurchatov Institute Russian Scientific Center i.e. Laboratory No.2.[11]

UNITED STATES ATOMS FOR PEACE PROGRAM

Research reactors in many countries around the world came from the United States by virtue of the “Atoms for Peace” Program proposed by President Eisenhower in 1953. He suggested that the Soviet Union and the United States transfer enriched uranium to a new international organization (what later became the International Atomic Energy Agency or IAEA). These transfers would form an “atomic bank” from which other countries could withdraw uranium for their peaceful nuclear programs. In the light of this program the United States, followed by the Soviet Union, France and other countries

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[10]The History of Nuclear Energy, Nuclear Engineering, U.S. Department of Energy Office of Nuclear Energy, Science & Technology, DOE/NE-0088; [http://www.nuc.umr.edu/nuclear_facts/history/history.html]

[11]Ministry for Atomic Energy of Russian Federation;[http//www.old.minatom.ru/english/about/history.html].

supplied research reactors and weapons grade HEU to burn in them to many countries around the world. In addition, IAEA was formed to provide information, assistance, training, and safeguards for peaceful development of atomic energy. In 1978, the US government started a program to convert the uranium it had supplied from HEU to LEU to prevent the HEU from being used to make nuclear weapons. The U.S. program to convert reactors from HEU to LEU is called the Reduced Enrichment for Research and Test Reactors (RERTR) Program. The RERTR program concentrates on reactors over 1 MW which have significant fuel requirements. Pursuant to this, 20 of the U.S. supplied HEU research reactors outside the United States had been converted from HEU to LEU by March 2002. Except for one new HEU reactor in Germany, no new HEU research reactors have been built in the Western world since RERTR began. However, U.S. supplied HEU reactors have not yet been converted in countries including: Argentina, Austria, Canada, France, Germany, Greece, Israel, Italy, Jamaica, Japan, Mexico, and Romania (Travelli, 2002).

Like the United States, the Soviet Union in 1978 launched its own program to reduce the enrichment of research reactor fuels it supplied to Eastern European Warsaw Pact countries, to Iraq, Libya, North Korea, and Vietnam. During the 1980s, the Soviet Union also changed its policies regarding the export of fuel for Soviet-built research reactors abroad, thenceforth supplying them with 36% HEU in lieu of 90% HEU. However, activities to reduce enrichment levels were hampered in the late 1980s by the economic and political problems within Russia. The situation got worse after the collapse of the Soviet Union.[12]

France also supplied large research reactors to other countries including Israel (uranium without enrichment) and Iraq (HEU fueled). According to the IAEA, government or industry research reactors with large HEU inventories were located in the year 2000 in Argentina, Australia, Austria, Belgium, Canada, Chile, China, Czech Republic, France, Germany, Greece, Hungary, Romania, Russia, South Africa, Switzerland, Taiwan, Ukraine, United Kingdom, United States, Uzbekistan, Vietnam, and Yugoslavia. Adding IAEA figures for operating research reactors to those that are shut down but may still house HEU fuel, there remain about as many HEU research reactors as LEU ones in the world (IAEA, 2000, 2002).[13] Through the “Atoms for Peace” Program U.S. exported 1,650 pounds of plutonium and 60,000 pounds of HEU to thirty-nine countries over thirty years.[14]

Pakistan has two swimming pool type material testing research reactors namely PARR-1 and MNSR having thermal power of 10 MW and 27 KW respectively. PARR-1 was provided by the US under the “Atoms for Peace” Program in 1962 which was, later on, in the 1990’s converted to low enriched uranium as a result of RERTR program. These reactors are mainly used for research studies in physics, isotope production, and training of engineers, scientists and technicians.

[12] Securing Nuclear War Heads and Materials Converting, Research Reactors; [http://www.nti.org/e_research/cnwm/securing/convert.asp].

[13] George Bunn, Chaim Braun;Terrorism Potential for Research Reactors Compared with Power Reactors; Center for International Security and Cooperation, Stanford University, American Behavioral Scientist, Vol. 46 No. 6, February 2003, 714-726.

[14] Graham Allison;Nuclear Terrorism, The Ultimate Preventable Catastrophe, Times Books, Henry Holt and Company, LLC, 115 West 18th Street, New York, 11001.

THE WORLD'S EXPERIENCE WITH RESEARCH REACTORS

The number of research reactors that have been constructed worldwide for civilian applications is about 651. Of the reactors constructed, 284 are currently in operation, 258 are shut down and 109 have been decommissioned.[15] Russia has the most research reactors (62), followed by the United States (54), Japan (18), France (15), Germany (14) and China (13). Many small and developing countries also have research reactors, including Bangladesh, Algeria, Colombia, Ghana, Jamaica, Libya, Thailand and Vietnam. About 20 more reactors are planned or under construction, and 361 have been shut down or decommissioned, about half of these in USA. Many research reactors were built in the 1960s and 1970s. The peak number operating was in 1975, with 373 in 55 countries.[16]

There is a much wider array of designs in use for research reactors than for power reactors, where 80% of the world's plants are of just two similar types. They also have different operating modes, producing energy which may be steady or pulsed. A common design (67 units) is the pool type reactor, where the core is a cluster of fuel elements sitting in a large pool of water. Among the fuel elements are control rods and empty channels for experimental materials. Each element comprises several (e.g. 18) curved aluminum-clad fuel plates in a vertical box. The water both moderates and cools the reactor, and graphite or beryllium is generally used for the reflector, although other materials may also be used. Apertures to access the neutron beams are set in the wall of the pool. Tank type research reactors (32 units) are similar, except that cooling is more active. The Training, Research and Isotope Production of General Electric (TRIGA) reactor is another common design (40 units). The core consists of 60-100 cylindrical fuel elements about 36 mm diameter with aluminum cladding enclosing a mixture of uranium fuel and zirconium hydride (as moderator). It sits in a pool of water and generally uses graphite or beryllium as a reflector. This kind of reactor can safely be pulsed to very high power levels (e.g. 25,000 MW) for fractions of a second. Its fuel gives the TRIGA a very strong negative temperature coefficient, and the rapid increase in power is quickly cut short by a negative reactivity effect of the hydride moderator. Other designs are moderated by heavy water (12 units) or graphite. A few are fast reactors, which require no moderator and can use a mixture of uranium and plutonium as fuel. Homogenous type reactors have a core comprising a solution of uranium salts as a liquid, contained in a tank about 300 mm diameter. The simple design made them popular early on, but only five are now operating.[17]

Fuel assemblies are typically plates or cylinders of uranium-aluminum alloy (U-Al) clad with pure aluminium. Only a few kilograms of uranium is needed to fuel a research reactor albeit more highly enriched (compared with perhaps a hundred tons in a power reactor). Highly-enriched uranium (HEU >20% U-235) allowed more compact cores, with high neutron fluxes and also longer times between refueling. Therefore, many reactors up to the 1970s used it, and in 2004 more than 60 civilian research reactors still did so. Most research reactors using HEU fuel were supplied by the US and

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[15] F. Alcala-ruiz, IAEA, H. Böck, Atom Institute of the Austrian Universities, Austria, F. Dimeglio, Consultant, United States of America, J.L. Ferraz-bastos, IAEA, S.C. Kim, IAEA, D. LitaI, Consultant, Israel, M. Voth, IAEA; Safety of Research Reactors; [http://*www.iaea.org/worldatom/Meetings/2001/infcn82-topical4.pdf].*

[16] Information Paper "Research Reactors", World Nuclear Association; [http://www.world-nuclear.org/info/inf61.html].

[17] Information Paper "Research Reactors", World Nuclear Association; [http://www.world-nuclear.org/info/inf61.html]

Russia. The RERTR program concentrates on reactors over 1 MW which has significant fuel requirements.[18]

RESEARCH REACTOR APPLICATIONS

Research reactors are widely used for scientific investigations and various applications. The radiation produced by research reactors is the key output, not the very little amount of energy produced. The most common use of this radiation is for experiments. Primarily, two types of radiation are used from research reactors: neutrons and gamma rays. Some experiments require more of one type radiation than the other. Neutrons produced by research reactors provide a powerful tool for studying matter on nuclear, atomic, and molecular levels. The amount and types of radiation may be controlled by placing different types of "filters" between the reactor and the experiment, or positioning the experiment at different locations relative to the radioactive fuel in the core.

Experimenters use different types of facilities to expose the material to the required types of radiation. Experimental facilities include in-core radiation "baskets," pneumatic (air-operated) tubes (similar to systems used at drive-through banks), and beam tubes (holes in the shielding around the reactor which can direct a beam of radiation to the experiment). Radiation is used to study material characteristics that cannot be readily measured otherwise. Following is the detail of some uses of research reactors;

Neutron Scattering

In this use, radiation from the reactor is directed at the material to be studied. The manner in which the radiation interacts and bounces off, or scatters, from the material yields information on structure and properties. Neutron scattering is an important tool in experiments dealing with superconductors, polymers, metals, and proteins. Researchers can analyze molecular structure, surfaces and interfaces, measure electronic and magnetic properties, stress and strain conditions, and gauge other characteristics.

Neutron Activation Analysis

This is another powerful tool used in the detection of very small (trace) amounts of material. It is used to measure the presence of trace elements such as environmental pollutants in soil, water, air, and foods with an accuracy of several parts per billion. Neutron activation may also be used to create new radioactive isotopes such as radio-pharmaceuticals (radioactive material used in medicine) and to process silicon prior to use in computer chips. Neutron activation is also used to produce the radioisotopes, widely used in industry and medicine, by bombarding particular elements with neutrons. For example, yttrium-90 micro spheres to treat liver cancer are produced by bombarding yttrium-89 with neutrons. The most widely used isotope in nuclear medicine is technetium-99, a decay product of molybdenum-99. It is produced by irradiating U-235 foil with neutrons and then separating the molybdenum from the other fission products in a hot cell.[19]

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[18] Information Paper “Research Reactors”, World Nuclear Association; [http://www.world-nuclear.org/info/inf61.html].

[19] Information Paper “Research Reactors”, World Nuclear Association; [http://www.world-nuclear.org/info/inf61.html].

Neutron Radiography

This is similar to medical or dental X-rays. These experiments are used to determine structural integrity for aerospace, automotive and medical components. This technique is also used for non-destructive inspection of components and materials, such as aircraft turbine blades and aerospace components.[20]

Production of Isotopes

This is used in biology, medicine, agriculture, industry, hydrology and research.

Industrial Processing

Research reactors can also be used for industrial processing. Neutron transmutation doping makes silicon crystals more electrically conductive for use in electronic components. In test reactors, materials are subject to intense neutron irradiation to study changes. For instance, some types of steel become brittle, and, therefore alloys which resist embrittlement must be used in nuclear reactors.[21]

Research and Test Reactors

This is involved in medical research using neutrons for the treatment of cancerous tumors or making radioisotopes for research and therapy. In addition, materials used in power reactors are irradiated in research and test reactors to assess the change in characteristics from exposure to radiation. These changes are important in assessing safety functions and in considering license extension for nuclear power plants. Another important role of research reactors is training of students and technicians needed to support the nuclear power industry.

Research Reactor Safety

The general safety objective in all nuclear installations is to protect individuals, society and the environment from harm by establishing and maintaining effective defense against radiological hazards. This safety objective requires that nuclear installations are designed and operated so as to keep all sources of radiation exposure under strict technical and administrative control.[22] Keeping this object in view, reactors are designed with the expectation that they will operate safely without releasing radioactivity to their surroundings. It is, however, recognized that accidents can occur.

An accident occurred on September 23, 1983 in the RA-2 Facility in Constituyentes, Argentina during operation of the research reactor. Two fuel elements had been placed outside the graphite reflector surrounding the reactor but had not been removed from the tank. A technician was changing the fuel configuration from the control room while moderating water was in the reactor, a procedural violation. A criticality excursion occurred, exposing the operator to a 3,700-rad dose (2000 rad gamma and 1700 rad neutron), with the upper right side of the body exposed the worst. The operator died 2 days later. Two others in the control room received doses of 35 rad each.[23] During the operation of research reactors to date: 16 criticality accidents, 11 loss of flow accidents, six loss of

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[20] Nuclear Science, Application of Research Reactors, AECL; [http://www.aecl.ca/Science/RR/Applications.htm].

[21] Information Paper "Research Reactors", [http://www.world-nuclear.org/info/inf61.html]

[22] IAEA Safety Series No. 110; [http://www-naweb.iaea.org/napc/physics/ACTIVITIES/Foreword.htm].

[23] Constituyentes research reactor accident, 1983; [http://www.johnstonsarchive.net/nuclear/radevents/1983ARG1.html].

cooling accidents, 25 erroneous handling/failure of equipment and two special events (external or internal) have been reported so far.[24] Since 1945 there have been at least 21 deaths from criticality accidents; seven in the United States, ten in the Soviet Union, two in Japan, one in Argentina, and one in Yugoslavia. Nine have been due to process accidents and the remaining are research reactor accidents.[25]

A "defense-in-depth" approach using multiple barriers has been adopted to deal with such accidents. These barriers include the fuel cladding, primary vessel, and shielding. The "defense-in-depth" strategy that protects the public from radiological hazard in the event of a reactor malfunction is also likely to protect the reactor's fuel and safety systems from attempted sabotage (this is defined in coming section). The design of each plant emphasizes the reliability of plant systems, redundancy and diversity of key safety systems, and strong physical barriers to prevent incidents that could pose a threat to public health and safety. As a final barrier, the reactor is housed in steel-reinforced concrete containment structures.[26]

The containment structures, coupled with multiple, redundant safety and plant shutdown systems, have been designed to withstand the impact of earthquakes, hurricanes, floods and airborne objects with a very substantial force. In 1988 Sandia National Laboratories in USA demonstrated the unequal distribution of energy absorption that occurs when an aircraft impacts a massive, hardened target. The test involved a rocket-propelled F-4 Phantom jet (weighing about 27 tons, with both engines close together in the fuselage) hitting a 3.7 m thick slab of concrete at 765 km/h. This was to investigate whether a proposed Japanese nuclear power plant could withstand the impact of a heavy aircraft. It showed how most of the collision energy goes into the destruction of the aircraft itself - about 96% of the aircraft's kinetic energy went into its destruction and some penetration of the concrete, while the remaining 4% was dissipated in accelerating the 700-ton slab. The maximum penetration of the concrete in this experiment was 60 mm, but comparison with fixed reactor containment needs to take account of the 4% of energy transmitted to the slab.[27] This consists basically of the reactor building, which is designed and tested to prevent any radioactivity that escapes from the reactor from being released to the environment.

As a consequence, the containment structure must be at least nominally airtight. In practice, it must be able to maintain its integrity under circumstances of a drastic nature, such as accidents in which most of the contents of the reactor core are released to the building. It has to withstand pressure buildups and damage from debris propelled by an explosion within the reactor, and it must pass a test to demonstrate that it will not leak more than a small fraction of its contents over a period of several days, even when its internal pressure is well above that of the surrounding air. The most common form of containment building is a cylindrical structure with a spherical dome. Other major safety systems that protect the core in emergency conditions are the emergency core cooling system

[24] Module II1 Overview of Radiation Emergencies; [http://www-ansn.iaea.org/.../II1_3%20Emergencies%20at%20Research%20Reactors.ppt-].

[25] [http://www.answers.com/topic/criticality-accident]

[26] Reactor Security: Multiple Safety Systems and Physical Construction; [http://www.nei.org/index.asp?catnum=2&catid=276] & [http://www.nei.org/index.asp?catnum=3&catid=290]

[27] Safety of Nuclear Power Reactors, Nuclear Issues Briefing Paper 14 January 2007; [http://www.uic.com.au/nip14.htm].

which makes it possible to cool the reactor if normal cooling is disrupted, and the emergency power system which is designed to supply electrical power in case the normal supply is disrupted.[28] Moreover, reactor operators act in combination with plant security systems to maintain safety**.** Reactor operators are trained frequently to ensure that they can respond to a range of unusual events. Plant operators have emergency procedures in place specifically for security situations, including automatic shutdown of the reactor in the event of an attack. In addition to the above, emergency planning and public notification systems are coordinated with plant security procedures to protect public health and safety. Plant personnel are trained in emergency procedures that would be used to keep the plant safe from a sabotage attempt.[29]

"DEFENSE-IN-DEPTH" AGAINST POTENTIAL THREATS

The concept of defense in depth in the design of the research reactor provides a series of levels of defense (inherent features, equipment and procedures) which are aimed at preventing accidents and ensuring appropriate protection in the event that prevention fails. Each of these levels mitigates the failure of the previous level and prevents the actuation of the next one. The defense-in-depth features that protect the public from radiological hazard in the event of a reactor incident also protect the plant's fuel and related safety systems from attempted sabotage. The design of each plant emphasizes the reliability of plant systems, redundancy and diversity of key safety systems, and other safety features to prevent incidents that could pose a threat to public health and safety. The containment built of reinforced concrete protects the reactor building against external accidents (e.g. an explosion or an aircraft crash). Human aspects of defense in depth are brought into play to protect the integrity of the barriers, such as quality assurance, administrative controls, safety reviews, independent regulation, operating limits, personnel qualification and training, and safety culture. Design provisions including both those for normal plant systems those for engineered safety systems help to prevent undue challenges to the integrity of the physical barriers, to prevent the failure of a barrier if it is jeopardized, and to prevent consequential damage of multiple barriers in series.[30]

Application of the concept of defense in depth in the design of the research reactor provides a series of levels of defense (inherent features, equipment and procedures) which are aimed at preventing accidents and ensuring appropriate protection in the event that prevention fails. However, defense in depth shall be applied with account taken of the graded approach and of the fact that many low power research reactors do not qualify for the fifth level of defense or even for the fourth level.

(1) The aim of the **first level** of defense is to prevent deviations from normal operation and to prevent system failures. This leads to the requirement that the nuclear installation shall be soundly and conservatively designed, constructed, maintained and operated in accordance with appropriate quality levels and engineering practices, such as the application of

[28]Information Paper "Research Reactors", [*http://www.world-nuclear.org/info/inf61.html*] and Reactor Security: Multiple Safety Systems and Physical Construction; [http://www.nei.org/index.asp?catnum=3&catid=290].

[29]Reactor Security: Multiple Safety Systems and Physical Construction; [http://www.nei.org/index.asp?catnum=2&catid=276]

[30]*Safety Report Series No. 46, Assessment of Defence in Depth for Nuclear Power Plants; [http://www-pub.iaea.org/MTCD/publications/PDF/Pub1218_web.pdf]*

redundancy, independence and diversity. To meet this objective, careful attention is paid to the selection of appropriate design codes and materials, and to control of the fabrication of components and control of the construction, operation and maintenance of the nuclear installation.

(2) The aim of the **second level** of defense is to control (by detection and intervention) deviations from operational states so as to prevent anticipated operational occurrences from escalating to accident conditions. This aim is framed in recognition of the likelihood that some postulated initiating events may occur at some point during the lifetime of the reactor, despite the precautions taken to prevent them. This level of defense necessitates the provision of specific systems, as determined in the safety analysis, and the definition of operating procedures to prevent or minimize damage resulting from such postulated initiating events.

(3) For the **third level** of defense, it is assumed that, although very unlikely, the escalation of certain anticipated operational occurrences or postulated initiating events may not be arrested by a preceding level of defense and a more serious event may develop. These unlikely events are anticipated in the design basis for the research reactor, and inherent safety features, fail-safe design, additional equipment and procedures are provided to control their consequences and to achieve stable and acceptable states of the nuclear installation following such events. This leads to the requirement that engineered safety features shall be provided that are capable of transferring the research reactor first to a controlled state and subsequently to a safe shutdown state, and of maintaining at least one barrier for the confinement of radioactive material.

(4) The aim of the **fourth level** of defense is to address beyond design basis accidents (BDBAs)[*] in which the design basis may be exceeded and to ensure that radioactive releases are kept as low as practicable. The most important objective for this level is the protection of the confinement function. This may be achieved by complementary measures and procedures to prevent accident progression, and by mitigation of the consequences of selected BDBAs, in addition to emergency procedures and intervention measures. The protection provided by the means of confinement may be demonstrated by using best estimate methods.

(5) The **fifth and final level** of defense is aimed at mitigation of the radiological consequences of potential releases of radioactive material that may result from accident conditions. This requires the provision of an adequately equipped emergency control center and plans for the on-site and off-site emergency response. Table 1 summarizes the objectives of each level and the corresponding means that are essential for achieving them.[31]

[*] The terms ‘severe accident’ and ‘accident management’ are not used in the present Safety Requirements publication

[31] IAEA Safety Standards; Safety of Research Reactors: NS-R-4; *[http://www-pub.iaea.org/MTCD/publications/PDF/Pub1220_web.pdf]*

TABLE I. LEVELS OF DEFENSE IN DEPTH[32]

LEVELS OF DEFENSE IN DEPTH	**OBJECTIVE**	**ESSENTIAL MEANS FOR ACHIEVING THE OBJECTIVE**
Level 1	Prevention of abnormal operation and failures	Conservative design and high quality in construction and operation
Level 2	Control of abnormal operation and detection of failures	Control, limiting and protection systems and other surveillance features
Levels 3	Control of accidents within the design basis	Engineered safety features and emergency operating procedures
Level 4	Control of severe plant conditions, including prevention of accident progression and mitigation of the consequences of severe accidents	Complementary measures and accident management
Level 5	Mitigation of radiological consequences of significant releases of radioactive materials	Off-site emergency response

Safety Analysis

The defense in depth concept is applied mainly through the safety analysis and the use of sound engineering practices based on research and operational experience. The analysis is carried out in the design to ensure that the safety objectives are met. The safety analysis shall include analyses of the response of the reactor to a range of postulated initiating events (such as malfunctions or failures of equipment, operator errors or external events) that could lead either to anticipated operational occurrences or to accident conditions. These analyses shall be used as the basis for the design of items important to safety and the selection of the operating and licensing conditions (OLCs) for the reactor. The safety analysis comprises of both deterministic and probabilistic approaches complementing each other. The analyses shall also be used as appropriate in the development of operating procedures, periodic testing and inspection programs, record keeping practices, maintenance schedules, proposals for modifications and emergency planning.[33]

All the regulatory requirements are meant for the safety of reactors and strengthening the physical barriers for the intended design life of the facility. The range of accidents with which plants must be

[32] *Safety Report Series No. 46, Assessment of Defence in Depth for Nuclear Power Plants; [http://www-pub.iaea.org/MTCD/publications/PDF/Pub1218_web.pdf].*

[33] IAEA Safety Standards; Safety of Research Reactors: NS-R-4; *[http:www-pub.iaea.org/MTCD/publications/PDF/Pub1220_web.pdf]*

designed to cope, has been decided on the basis of their predicted accidental likelihood as well as severity of their outcome. However, calculations of accidental likelihood are not relevant for terrorist acts.[34]

Defense-in-depth for the research reactor in Pakistan is achieved through sound design, construction, testing, maintenance, training and guidance of operating personnel. The control system, protection system, and safety systems provide additional protection during normal operation, abnormal occurrences and in case of design basis accidents. In addition, suitable physical protection measures are adopted to cope with some sabotage acts.

POSSIBILITY OF TERRORIST ACTS ON RESEARCH REACTORS

To date, various types of research reactors round the world such as: TRIGA, Material Testing Reactors, Advanced Test Reactor (ATR), MAPPLE, Proto Type Reactors, and Zero Power Critical Assemblies, are designed and operated successfully. Similarly, most Soviet/Russian-designed research reactors are technically very similar to the MTR-type reactors of U.S. design. The pool-type reactors of the so-called IRT-type are the main Soviet/Russian design of the medium-sized reactors. Again, for cooling purposes, the Soviet/Russian reactors of higher power levels are tank type. The main representatives of this class are the light-water-moderated reactors of the VVR class.

During the design of these reactors it is considered that the core damage can result from several different classes of accidents that include: reactivity excursions, blockage of primary coolant flow, and loss of primary coolant. The relative severity of these accident classes is dependent on reactor-specific issues of design, power level, type of fuel, and the availability of additional on and off-site safety systems. The reactors are provided with safety systems that can operate in case of accidental conditions in order to avoid undue risk of radiation to the public and the environment. Their design is such that it can withstand environmental conditions. However, these are not designed to cope with the malicious acts of terrorists.

The design of research reactors is simple as compared to the nuclear power plants so the saboteurs would need to attack fewer targets to achieve core damage. There are various modes of sabotage for research reactors, including the direct use of explosives next to the core to disperse it. This is because, unlike a power reactor core, the mass of a typical research reactor core is comparable to the mass of explosives that could be easily transported to the site, and the core is likely to be much more accessible than the core of a power reactor’s. There is a possibility that this could cause a breakdown of the cooling system resulting in a core melt. Damage to the reactor and its confinement system could also be caused by explosives delivered by hand, vehicle bombs, missiles and small aircraft.

It may be probable that terrorists' may use anti-tank weapons to destroy the most important control systems causing damage to reactor core. We can't exclude the possibility of bombers' using a high-jacked airplane with full fuel tanks for a powerful blow on a research reactor. Since terrorism is one of worldwide concern, the possibility of terrorist attacks on these facilities anywhere in the world cannot be ruled out.

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[34] Terrorist Attack on Nuclear Facilities; Post Note, July 2004, number 222.

OVERVIEW OF THE SECURITY OF RESEARCH REACTORS

The September 11th attack demonstrated that terrorists are capable of successfully attacking fixed infrastructures with a large jetliner. Location could play a significant role in the choice of which facilities to attack. The locations of research reactors are mostly in suburban districts and university campuses, in industrial zones and on the campuses of national laboratories and research centers. Reactors in large population centers where an act of sabotage would have the most serious consequences would be the most attractive to terrorists.[35] In the United States, there are many research reactors operating in urban centers and universities for scientific research, training and radioisotope production for medicine and industry as well as for the testing of material. Although the inventory of radioactive materials in such facilities is far smaller than that of nuclear power stations, security at most research reactors is very limited, which could make them potentially attractive targets for terrorist groups.[36]

On the basis of their analysis of the security status of research reactors and the possible nature of terrorist threats, U.S. scientists warn the most dangerous consequences could take place in attacks on reactors of medium (1-10 MW) and large (10-250 MW) capacity. Here there is a significant quantity of radioactive materials and in addition they are more weakly protected against outside attack than nuclear power station reactors.[37] Three nuclear research reactors operated by Massachusetts colleges and universities could be easy targets for terrorist attacks because they lack the stringent security required of larger commercial nuclear power plants, critics and nuclear security experts charge. "These things are just a disaster. They should all be shut down," said Peter Stockton, an expert on reactor security with the Project on Government Oversight, a government watchdog organization.[38] Specialists also point to the possibility of terrorists using rocket-propelled antitank weapons to carry out a strike against a reactor's most important security systems. In particular, they could put rockets on truck, launch them against a reactor within direct sight range, and put its control system out of action. This could lead to a failure of the facility's cooling system and an increase in reactivity (the intensiveness of the nuclear chain reaction), as a result of which the reactor core would melt down and discharge decomposition products. Nor can we exclude the possibility of suicide terrorists using a hijacked aircraft with full fuel tanks to carry out a powerful strike against a research reactor.[39]

A group of highly prestigious American scientists have analyzed the state of security at research nuclear reactors and published the results of their work in the journal.[40] Their conclusions are very worrying. One of them is that the general improvement in the nuclear security system have thus far applied to a far lesser extent to research reactors, which exist on the territory of more than 40

[35] Strengthening the Global Partnership; [http://www.sgpproject.org/Personal%20Use%20Only/RUBelous.html].

[36] Charles D. Ferguson; The Four Faces of Nuclear Terrorism; Center for Nonproliferation Studies, 460, Pierce Street, Monterey, California, USA.

[37] Russian Commentary Examines Risks of Terrorist Attacks on Research Reactors; [http://www.sgpproject.org/Personal%20Use%20Only/RUBelous.html].

[38] A Project on Government Oversight Archives; [http://www.pogo.org/p/x/archivesecurity.html]

[39] Russian Commentary Examines Risks of Terrorist Attacks on Research Reactors; [http://www.sgpproject.org/Personal%20Use%20Only/RUBelous.html].

[40] Science and Global Security; [http://www.sgpproject.org/Personal%20Use%20Only/RUBelous.html].

countries. Such serious concern is explained first and foremost by the fact that these reactors are the main nonmilitary consumers of highly enriched uranium (HEU). The article further stated, however, it should be borne in mind that research reactors, as a rule, are located within the city limits or close to university campuses, while nuclear power stations are located at considerable distances from population centers. This leads to an increased level of danger posed by possible acts of sabotage against research reactors for the population nearby. Also the reactors in large population centers where acts of sabotage would have the most serious consequences will be the most attractive to terrorists.[41]

Three aspects of research reactors might make them less safe and secure than typical commercial nuclear power reactors. First, many of the low power (less than 2 MW thermal out put) research reactors in the United States lack containment structures and even the higher power research reactors typically use containment structures that are considerably weaker than those used by commercial reactors. Second, most research reactors lack adequate exclusion zones to guard against the potential for truck bombs, and the perimeter protection "is typically a wire fence without anti-vehicle barriers, motion sensors, or electronic/computer based detection and assessment systems one finds at commercial nuclear power plants." In addition, many research reactors are located on university campuses, where security tends to be less rigorous than at commercial reactor site. In particular, "many research reactors operated by universities and sometimes by industry are open to visiting specialists (if not to the general public) and have fewer protective security practices than typical nuclear power plants". An added concern is that many university campuses are located in or near cities or high density suburban population zones. About 50 % of the high power operational research reactors in the United State are within 10 miles of population zones containing 500,000 or more people. This group includes reactors in or near Washington, D.C; Cambridge, Massachusetts; Denver, Colorado and Austin, Texas. Nuclear power reactors, in contrast, typically are located in more isolated settings, although there are a number of important exceptions to this rule.

In the report to congressional requesters, Government Accountability Office (GAO) under scored that "sleeping guards, unauthorized access to protected areas, disabled alarms in vital areas, and failure to inspect visitors who set off alarms on metal detectors are all serious security problems that warrant NRC attention and oversight".[42]

According to a group of Russian sociologists and former workers at nuclear facilities, alcoholism and drug abuse are prevalent at Russia's nuclear power plants and the reprocessing facility at Mayak. Vladmir Lupandin, a researcher with the Institute of Sociology affiliated with the Russian Academy of Sciences, said "A nuclear power plant does not fight alcoholism, it propagates it. Alcoholics are advantageous for nuclear power plants, they are modest and undemanding." Sergei Kharitonov, who had worked for 27 years at the Leningrad Nuclear Power Plant (an RBMK facility) and who now works for the Norwegian Environmental Group, Bellona, charged that this plant has "a total lack of a culture of security". The news report cited a Ministry of Atomic Energy of the Russian Federation

[41] Russian Commentary Examines Risks of Terrorist Attack on Research Reactors; [http://www.sgpproject.org/personal20%Use%20Only/RUBelous.html].

[42] GAO Report to Congressional Requesters; Nuclear Regulatory Commission; Oversight of Security at Commercial Nuclear Power Plants Needs to Be Strengthened; [www.gao.gov/new.items/d03752.pdf].

(MINATOM) spokesperson as saying that alcohol and drug abuse are less prevalent in cities with nuclear facilities than other Russian cities.[43]

In exercises designed to test security, US Army and Navy teams successfully penetrated nuclear facilities and obtain nuclear materials. The US took legislative measures to increase security at and around nuclear facilities.[44]

NUCLEAR TERRORISM AND PAKISTAN VULNERABILITY

An often said aphorism in the nuclear safety field is "a nuclear accident anywhere is a nuclear accident everywhere".[45] In the light of 9/11, one can say that "a nuclear terrorist act anywhere is a nuclear terrorist act everywhere". Even before 9/11, terrorist threats have been made against research reactors. On November 11, 1972, a DC-9 plane was hijacked in the US, the hijackers threatened to ditch the plane into the Oak Ridge nuclear research reactor, the plane circled the reactor plant for one hour, the reactor was shut down and the plant was evacuated (except for essential personnel).[46] Similarly, the probability of nuclear terrorism by enemy states cannot be ruled out.

- Iran bombed the Al Tuwaitha (in Iraq) nuclear complex in September 1980 but inflicted little or no damage.

- Iraq bombed Iran's Bushehr nuclear plant (which included two partly-built power reactors) at least six times between March 1984 and November 1987.

- The US bombed two small, safeguarded nuclear reactors (the 5 MW(th) IRT-5000 Soviet-built pool-type reactor, and a French-supplied 0.5 MW(th) critical facility called Tammuz-II), and other nuclear sites such as uranium hexafluoride conversion and centrifuge enrichment pilot facilities, in Iraq in 1991.

- Iraq launched Scud missiles at the Israeli Dimona plant in 1991.[47]

- In addition, June 7, 1981, 16 US-made Israeli warplanes bombed and destroyed Iraq's Osirak nuclear research facility.[48]

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[43] Charles D. Ferguson; The Four Faces of Nuclear Terrorism; Center for Nonproliferation Studies, 460, Pierce Street, Monterey, California, USA.

[44] The Nuclear Age Peace Foundation's Top Five List of Events Related to Nuclear Terrorism in 2001; http://www.nuclearfiles.org/menu/timeline/top-five-events-terrorism-2001.htm]

[45] Charles D. Ferguson; The Four Faces Of Nuclear Terrorism; Center for Nonproliferation Studies, 460, Pierce Street, Monterey, California, USA.

[46] Jim Green, PhD; Research Reactors and Nuclear Weapons; [*http://www.mapw.org.au/nuclear-reactors/02green.html*].

[47] Jim Green, PhD; Research Reactors and Nuclear Weapons; [*http://www.mapw.org.au/nuclear-reactors/02green.html*]

[48] Israel Bombs Iraq's Osirak Nuclear Research Facility [http://www.wrmea.com/backissues/0695/9506081.htm].

Because the research reactors contain much less radioactivity than commercial reactors, a devastating attack on research reactor would not cause nearly as much as damage as a similar attack on nuclear power plants assuming that both the reactors are from equal distance from population centers. Small research reactors-100 thermal kilowatt (kWth) to 1 MWth contain a maximum of 0.1 MCi of fission products in their cores, medium size reactors (1 MW-10 MWth) hold about 1-10 MCi of radioactivity and large research reactors (10 MWth to 250 MWth) contain up to 100 MCi. Thus, the consequences of a devastating attack on typical research reactor would be orders of magnitude less than the effects from an extremely damaging attack on a commercial reactor.[49] After 9/11, the Swiss nuclear regulatory authority stated that "from the construction engineering aspects, nuclear power plants (worldwide) are not protected against the effects of warlike acts or terrorist attacks from the air….one cannot rule out the possibility that fuel elements in the fuel pool or the primary cooling system would be damaged and this would result in a release of radioactive substances."[50]

Other recent events, though, suggest that a terrorist attack against a nuclear facility remains a serious threat. In March 2003, National Guard troops in Arizona descended on the Palo Verde Nuclear Power Plant-which is about 50 miles west of Phoenix and is the nation's largest nuclear power plant in terms of electric generating capacity- in response to a federal alert that the plant might be in danger from the terrorist attack. US Department of Homeland Security (DHS) Secretary Tom Ridge said that authorities had received information that was "serious enough, deemed to be credible enough", but he declined to provide details. He ordered one of the Custom Service's Black Hawk helicopters to the plant's site to increase physical protection measures. One of the most serious acts of sabotage against a nuclear power plant occurred in 1982 in South Africa. It was carried out by the antiapartheid movement headed by the African National Congress (ANC) which, on December 18, 1982, detonated four bombs over a period of several hours at the newly commissioned Koeberg nuclear power station. South African authorities at that time had claimed that this facility was one of the most heavily guarded sites in that country. As the first nuclear power plant in South Africa, Koeberg represented a highly symbolic target. Because the plant had not yet begun operation, the attack by the nationalists group intentionally did not result in a massive release of radiation. The attackers also claimed that they timed the explosions to take place on a Saturday when few people would be at site.

On October 14, 2002, Greenpeace activists easily entered the property of the Sizewell B nuclear power plant in Suffolk, England. About 25 minutes elapsed before two private security guards encountered the encroachers. Although Green Peace designed this activity as protest against new nuclear reactors in Great Britain, the breach inadvertently demonstrated the inadequate security at the plant. Similarly, in August 2003 authorities arrested 19 men on charge of attempting to harm the Pickering plant. For the foreseeable future, the nuclear power plants with the greatest inherent

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[49]Charles D. Ferguson; The Four Faces Of Nuclear Terrorism; Center for Nonproliferation Studies, 460, Pierce Street, Monterey, California, USA.

[50]Swiss Federal Nuclear Safety Inspectorate (HSK), Memorandum, "Protecting Swiss Nuclear Power Plants Against Airplane Crash"(undated), p.7. This memo also describes Swiss protection requirements as mentioned in the report titled Reducing the Hazards From Stored Spent Fuel Power Reactor Fuel in the United States' Robert Alvarez, Jan Beyea, Kalus Janberg, Jungmin, Kang, Ed Lyman, Allison Macfarlane, Gordon Thompson, Frank N. Von Hipple.

vulnerability to terrorist attacks are the Soviet designed plants lacking containments.[51] Three of the eight Sydney men arrested on terrorism charges in Australia in November 2005 had previously been stopped by police near Australia's only nuclear reactor in December 2004, raising the possibility that the Lucas Heights research reactor and its spent fuel store (situated 25 miles southwest of central Sydney) may have been a target.[52] When interviewed separately by police in 2004 all three gave different versions of the day's events and police inquiries revealed the access lock for a gate to a reservoir at the reactor had recently been cut. This was not the first time the Australian reactor had been the subject of a suspected terrorist plot. An earlier conspiracy was discovered in March 2000.[53]

Major attacks continue, recently with the suicide bomber who killed at least 42 soldiers in Dargai.[54] On July 19, 2007, at least 18 people were killed in a suicide bomb attack inside a mosque in the cantonment area of Kohat. Also, five civilians and a policeman were killed when a suicide bomber rammed an explosive laden vehicle into the main gate of a police parade ground.[55] On July 20, 2007, 30 persons died when suicide bomber tried to ram his car bomb into a van taking Chinese Engineers to Karachi from Hub but missed the target when a police van blocked its way.[56] Pakistan has experienced several incidents of terrorism but these were very target specific and mostly in retaliation to some action taken domestically or outside our country. None of the terrorist action was designed to kill a large population or to cause panic on a large scale. And while no such terrorist action was ever directed towards a nuclear installation, radiation facility, or any other hazardous industries a change of strategy by the terrorists cannot be ignored.

POSSIBLE MODES OF SABOTAGE ATTACKS

It is possible to imagine a wide range of terrorist attacks against nuclear facilities. Each would have a range of potential consequences depending on the characteristics of the attack and the facility being targeted as well as any post attack mitigating actions to prevent or reduce the release of radioactive material. It is difficult to determine the probability of these attacks for carrying out protective measures. Similarly, "it is possible to estimate the risks of industrial accidents because there are sufficient experiences and data to quantify the probabilities and consequences. This is not the case for a terrorist attack". To date, experts have not found a way to apply these quantitative risk equations to terrorist attacks because of two primary difficulties; the first is to develop a complete set of bounding scenarios for such attacks; the second is to estimate their probabilities. These depend on impossible-to-quantify factors such as terrorist motivations, expertise, and access to technical means. They also depend on the effectiveness of measures that might prevent or mitigate such attacks.[57] The NRC's standard approach to estimating the probabilities of nuclear accidents has been to relay on fault tree

[51] Charles D. Ferguson; The Four Faces of Nuclear Terrorism; Center for Nonproliferation Studies, 460, Pierce Street, Monterey, California, USA.

[52] Nuclear Link to Terror Suspects, BBC 14th November 2005; [http://news.bbc.co.uk/1/hi/world/asia-pacific/4434270.stm].

[53] *Nuclear Power and Security Threats, [www.no2nuclearpower.org.uk/reports/Security.pdf].*

[54] Pakistani Newspaper "Daily Dawn" dated November 9, 2006; [http://www.dawn.com.pk].

[55] Pakistani Newspaper "Daily DAWN", dated July 19, 2007; [http://www.dawn.com.pk]

[56] Pakistani Newspaper "Daily DAWN", dated July 19, 2007; [http://www.dawn.com.pk]

[57] Safety and Security of Commercial Spent Fuel Storage, The National Academy Press, Washington D.C.; [www.nap.edu].

analysis. This involves quantitative estimates of the probability of release scenarios due to sequences of equipment failure, human error, and acts of nature. But "no established method exists for quantitatively estimating the likelihood of a sabotage event at a nuclear facility."[58] However, the risk assessment data are not sufficient to determine quantitatively the likelihood of such damaging terrorist attacks. A qualitative assessment indicates that–due to the complexity of organizing a successful terrorist assault on a nuclear facility and the defense-in-depth safety and security features at nuclear plants-most attacks would fall short of massive release to environment.[59]

Worst-case scenarios are precisely the ones that terrorists have in mind when planning attacks.[60] The following modes of attack might be used against a typical research reactor:

- Truck Bomb
- Anti Tank Weapons
- Raid (Commando type attack by land)
- Air Plane or Helicopter
- Insider Collusion

Above examples are based upon past terrorist attacks on other facilities and upon the weapons known to be available to terrorists or that could be available to terrorists.[61] The detail of these follows.

Scenario I: Truck Bomb

Concerns about the truck bomb attacks against the nuclear facilities date back at least to the 1983 vehicular bombings in Lebanon against American assets. On April 18 of that year, the US Embassy in Beirut experienced a devastating truck bomb attack, and on October 25, the Marine barracks in Lebanon suffered a similar attack. In response to these events, the NRC issued a requirement for licensees to install truck bomb barriers and incorporated this vulnerability into the design basis threat for all US nuclear power plants. By February 1996, the NRC reported that all U.S. nuclear power plants had installed adequate vehicular control systems.[62]

Such an attack could be carried out in two ways. (1) Truck bomb is detonated near the perimeter fence, aimed at vital system support components of the research reactor, or (2) Suicide commandos, equipped with several four-wheel-drive vehicles, break through the barrier, drive towards vital system support components and detonate on-board explosives. In case (1), insider support is crucial for

[58]Robert Alvarez, Jan Beyea, Kalus Janberg, Jungmin, Kang, Ed Lyman, Allison Macfarlane, Gordon Thompson, Frank N. Von Hipple; Reducing The Hazards From Stored Spent Fuel Power Reactor Fuel in the United States].

[59]Charles D. Ferguson; The Four Faces Of Nuclear Terrorism; Center for Nonproliferation Studies, 460, Pierce Street, Monterey, California, USA.

[60] Impacts of a Terrorist Attack at Indian Nuclear Power Plant; *www.ucsusa.org/.../nuclear_terrorism/impacts-of-a-terrorist-attack-at-indian-point-nuclear-power-plant.html*

[61]George Bunn, Chaim Braun, Alexander Glaser, Edward Lyman, Fritz Steinhausler;Research Reactor Vulnerability to Sabotage by Terrorist; Science and Global Security.

[62]Charles D. Ferguson; The Four Faces of Nuclear Terrorism; Center for Nonproliferation Studies, 460, Pierce Street, Monterey, California, USA.

supplying the information on blast susceptible areas of the research reactor; furthermore, a four-wheel-drive vehicle capable of transporting about 1 ton of the explosive material close to the perimeter fence is needed. Case (2) would require a suitable truck loaded with explosives, capable of breaking through the fence(s) and/or concrete barrier(s), with other trucks following through the gap created by detonation of the first truck. The feasibility of either truck bomb attack mode is considerable. Large truck bombs have been used successfully against nonreactor US facilities in the past (e.g., U.S. Embassy in Beirut, April 1983; U.S. Marine barracks and French military headquarters in Lebanon, 1983; World Trade Center in New York City, 1993; Oklahoma City Federal Building, 1995; Khobar Towers, U.S. military housing in Saudi Arabia, 1996; two U.S. embassies in East Africa, 1998).[63]

Scenario II: Anti-Tank Weapons

One or more vehicle-mounted rocket-propelled grenades are fired against vital system support components. Insider support would be crucial for supplying the information on grenade-susceptible areas of the research reactor; also, direct line of sight to the reactor from the grenade launching site is essential. Rocket-propelled grenades are widely available at relatively low cost on the black market. They are the weapon of choice in the hands of terrorists whenever a concrete and/or steel layer is to be overcome in an attack (e.g., concrete building; armored vehicle).[64] Five anti-tank rockets were fired at the Creys-Malvillee Superphoenix full scale breeder reactor, near Lyon, France in January 1982. The reactor was still under construction and apart from damaging the outer shell of the building; little damage was done by the attack.[65] Specialists indicate the possibility of terrorists using reactive anti-tank weapons for a blow at the most important system of reactor security. For example, they can put on a lorry rockets that will be launched at the reactor and will wreck the control system. That may cause a breakdown of the cooling system and increase of reactivity (intensity of a nuclear chain reaction), as a result of this, melting of the active reactor zone and emission of nuclear decay will take place. We can't exclude possibility of bombers' using a high-jacked airplane with full fuel tanks for a powerful blow on a research reactor.[66]

Scenario III: Raid (Commando type Attack by Land)

A group of terrorists covertly puts explosives next to the core or vital system support components of the research reactor and at the fresh and spent fuel storage site; later, by remote control the group detonates the explosives. This would require a detailed study of the onsite conditions and/or help of an insider, military-style training, automatic weapons, explosives, and remote triggering mechanisms.

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[63] George Bunn, Chaim Braun, Alexander Glaser, Edward Lyman, Fritz Steinhausler;Research Reactor Vulnerability to Sabotage by Terrorists; [http://iis-db.stanford.edu/pubs/20365/11_2-3Bunn.pdf].

[64] George Bunn, Chaim Braun, Alexander Glaser, Edward Lyman, Fritz Steinhausler; Research Reactor Vulnerability to Sabotage by Terrorists; [http://iis-db.stanford.edu/pubs/20365/11_2-3Bunn.pdf].

[65] Russell D. Howard, James J. Forest; Weapons of Mass Destruction and Terrorism; McGraw Hill, Contemporary Learning Series.

[66] Where Should We Wait for New Blow of Terrorists? Defense and Security/Nezavisimaya Gazeta July 11, 2005/July 8, 2005; [http://www.sgpproject.org/Personal%20Use%20Only/RUBelousNuclearCenterTerrorist.html].

The feasibility of such an attack is possibly high in the US.[67] In 1973, a group of EPR terrorists attacked a nuclear power plant, which was not yet operational, near Buenos Aires, Argentina.[68] The Electric Power Research Institute (EPRI) study found that risks to the public health and safety from a terrorist ground attack on a commercial nuclear power plant are very low. In more than 90% of the scenarios, ground based terrorist attacks on a nuclear plant would not result in a radiation release severe enough to pose public health risk."[69]

Scenario IV: Air Plane or Helicopters

The 9/11 terrorist attacks have given official credibility to the use of wide-body civilian aircraft as weapons, however, no nuclear facility has been specifically designed to withstand such an attack.[70] In the opinion of experts, two modes of attack are feasible.

1. Suicide commandos crash several hired business jets (loaded with explosives and fully fuelled), or crash a hijacked large civilian aircraft (fully fuelled), into a research reactor.
2. Terrorists fly several hired helicopters or a refurbished and rearmed surplus military attack aircraft in an attack on a research reactor with military weapons.

Case (1) requires suicide commandos, trained to crash civilian aircraft into a research reactor; case (2) requires training in flying a helicopter or military plane, as well as the acquisition of military weapons, such as rocket-propelled grenades. Both scenarios require adequate time to deviate from the cleared flight plan (despite many flight restrictions near nuclear establishments) in order for the plane(s) or weapons to hit the research reactor.

For both cases, feasibility is low to medium. Although it is relatively easy to lease business jets, considerable skills are needed to actually hit the small cross-section of the target area of a research reactor to cause an uncontrolled release. On the other hand, criminals have demonstrated successfully the use of chartered or hijacked helicopters to attack security facilities (e.g., for armed jail breaks). Furthermore, the high speed of a military plane would increase the surprise element in the attack, and its sophisticated arms are likely to inflict significant damage (e.g., the 1981 Israeli aircraft bombing and destruction of the Iraqi research reactor).[71]

The consequences of air attacks are scenario and plant design specific. Experts suggested that the consequence of a heavy air craft crash on a nuclear installation depends on the following factors:

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[67]George Bunn, Chaim Braun, Alexander Glaser, Edward Lyman, Fritz Steinhausler; Research Reactor Vulnerability to Sabotage by Terrorists; [http://iis-db.stanford.edu/pubs/20365/11_2-3Bunn.pdf].

[68] Russell D. Howard, James J. Forest; [Weapons of Mass Destruction and Terrorism; McGraw Hill, Contemporary Learning Series].

[69] Charles D. Ferguson; The Four Faces Of Nuclear Terrorism; Center for Nonproliferation Studies, 460, Pierce Street, Monterey, California, USA.

[70] International Union, Security, Police and Fire Professionals of America, (SPFPA), SPFPA Index Page; [http://www.spfpa.org/nucleardivision.html].

[71]George Bunn, Chaim Braun, Alexander Glaser, Edward Lyman, Fritz Steinhausler; Research Reactor Vulnerability to Sabotage by Terrorist; Science and Global Security.

- Type and the design of the aircraft
- Speed of the aircraft
- Fuel loading of the aircraft and total weight at impact
- Angle of attack and point of impact of the facility
- Construction of the facility
- Location of the target with respect to ground level (i.e. below or above grade)
- The presence of surrounding buildings and other obstacles (e.g. hills, transmission lines) that might block certain potential flight paths into the facility.[72]

Since the World Trade Center attacks in New York in 2001, there has been concern about the consequences of a large aircraft being used to attack a nuclear facility with the purpose of releasing radioactive materials. Various studies have looked at similar attacks on nuclear power plants. They show that nuclear reactors would be more resistant to such attacks than virtually any other civil installations. A thorough study was undertaken by the US Electric Power Research Institute (EPRI) using specialist and consultants paid for by the US Department of Energy. It concluded that US reactor structures "are robust and (would) protect the fuel from impacts of large commercial aircraft".[73] In 2002, the nuclear industry researched the effects of airplane attacks against nuclear facilities. Analysis sponsored by the Electric Power Research Institute (EPRI) and the Nuclear Energy Institute (NEI) wrote the industry report. Using aircraft ground speed and attack angles associated with the 9/11 Pentagon attack, preliminary results released on June 17, 2002, indicated that containment buildings "can safely protect the reactor against most commercial air crafts," including 757s (the type used in the Pentagon attack) and 777s.[74] For the final report, completed in December 2002, the authors simulated the impact of a Boeing 767-400 into four types of structure: containment buildings, spent fuel storage pools, spent fuel dry storage facilities, and spent fuel transportation containers. Under all scenarios, the simulated air plane crash did not result in release of radioactivity to the environment. The containment buildings suffered "some crushing and spalling (chipping of material at the impact point) of the concrete". The spent fuel pools experienced "localized crushing and cracking of the concrete wall", but pools "were not breached," according to the prediction derived from the analysis.[75]

Scenario V: Insider Collusion

In late 2002, then-NRC Chairman Richard Meserve said, "The most difficult [threat] to defend against is the insider". Insiders aligned with terrorists pose major threats to nuclear facilities because they can provide knowledge about plant structure, operations, and vital equipment locations during the planning for an attack and can help disable essential plant systems during an attack. In addition, insider collusion represents a grave danger because it can accelerate the terrorist attack, impair timely

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[72] Safety and Security of Commercial Spent Fuel Storage; The National Academy Press, Washington D.C. [www.nap.edu].

[73] Safety of Nuclear Power Reactors, Nuclear Issues Briefing Paper 14, January 2007; [http://www.uic.com.au/nip14.htm].

[74] Nuclear Plant Damage from Air Attack Not Likely; Nuclear News: August 2002, p-21.

[75] Electric Power Research Institute, "Deterring Terrorism: Air Craft Crash Impact Analyses Demonstrate Nuclear Power Plant's Structural Strength," Nuclear Energy Institute, December 2002.

detection and response, and facilitate simultaneous targeting of vulnerable systems.[76] It is strongly believed that there is virtually no protection against sabotage by an insider.[77] Even where nuclear facilities are adequately protected against external attack, the threat of action by insiders would remain. The insider threat is particularly difficult to resolve because nuclear facilities typically employ large numbers of people and certain employees must have access to vital areas of the facility in order to perform their work. Exampled of past incidents involving the insider threat range from the relatively inconsequential to events quite costly to the company involved but not dangerous to the public to occurrences that are potentially very serious. All these point to the difficulties in protecting nuclear material and facilities from insiders.[78] The scenario of insider sabotage is particularly problematic in the former Soviet Union, where the prestige of the nuclear industry plunged in the wake of the 1986 Chernobyl accident. In addition, with the breakup of the former Soviet Union, the wages of employees at nuclear facilities plummeted. Underpaid nuclear workers could easily become prey for terrorist groups looking for a contact on the inside. Disgruntled employees also pose a threat as lone actors. They might sabotage the facility in order to express anger with their superiors or in an attempt to extort funds.[79]

Here are few examples how an insider or conspiracy of insiders could cause immeasurable harm through sabotage.

In 1981 at the Beaver Valley nuclear power plant near Liverpool, Ohio, someone shut a valve to the high head safety injection pumps, a crucial part of the emergency core cooling system (ECCS), an act that disabled the high pressure portion of the ECCS. This act could have been serious had there been an incident in which that system were needed (ex. a small loss of coolant where high pressure injection of emergency cooling water would have been necessary). The consensus of opinion was that act was intentional.[80] In 1981, at the Nine Mile Point Unit 1 nuclear power plant in Oswego, New York, the NRC found what it described as a "major degradation" of the backup power supply needed in case of a loss of off-site power. Diesel generators failed to start when tested because of an apparently deliberate closure of the drains on the fuel oil filters. It was concluded that the problem

[76]Charles D. Ferguson; The Four Faces Of Nuclear Terrorism; Center for Nonproliferation Studies, Nuclear Threat Initiative, 460, Pierce Street, Monterey, California, USA.
[77]S. Gopal; Nuclear Terrorism: Relevance and Prospects in South Asia; [*http://www.saag.org/papers4/paper359.html*].
[78]Daniel Hirsc; The Truck Bomb and Insider Threats to Nuclear Facilities; Nuclear Control Institute, Washington, D.C. [*http://www.nci.org/g-h/hirschtb.htm*].
[79]Bukharin, "Upgrading Security At Nuclear Power Plants In The Newly Independent State", pp 31-32.
[80]NRC "Report to Congress on Abnormal Occurrences, July-September 1981," NUREG-0090-, Vol4, no 3 (Washington, DC, January 1982), NRC Inspection report 50-334/81-16 for Beaver valley Power Station, December 10, 1981, NRC "Summary of incidents that May have Involved deliberate acts directed Against Plant Equipment in Vital Areas of Operating Reactor (1980-82), "Attachment to letter from then NRC Chairman Nunzio J Palladino to congressman Edward J Karkey, February 7, 1983".

was the result of tampering.[81] At the Salem Unit II nuclear power plant in Salem, New Jersey, in August 1982, the manual isolation stop valves to the air start motors to the number 2C diesel generator were found closed. The condition would have prevented both automatic and manual startups of the diesel generator were it needed in an emergency (such as loss of off-site power). The event occurred despite increased precautions by the licensee put in place after an act of suspected sabotage the previous week.[82] In 1979, two plant operator trainees at the Surrey nuclear power station in Newport News, Virginia, entered the fuel storage building, which was locked and alarmed, and poured sodium hydroxide on sixty two of sixty four new fuel assemblies stored there, damaging them. Both individuals had authorized access to the storage building.[83]

It is however, illustrative, of how sabotage could take place and remain undetected for a long period of time. At Turkey Point, a shared auxiliary feed water system supplies two reactors at the site. The system provides feed water system when the main system is not in service or when only small feed water flows are required. While one reactor was down for maintenance, someone closed the feed water system for the operating unit. For five days, no one noticed that the system had been rendered inoperable, despite a requirement that a thorough check be performed twice per shift. The failure to detect the disabling of the feed water system occurred apparently because the checks were not adequately detailed in instructions and because appropriate "out of maintenance" tags had been placed on the inappropriately closed valve. Had normal feed water flow been interrupted during that period, a serious situation, including the potential for core damage, could have resulted because auxiliary system was shut off.[84]

PHYSICAL PROTECTION REQUIREMENTS

Physical protection against the theft or unauthorized diversion of nuclear materials and against the sabotage of nuclear facilities by individuals or groups has long been a matter of national and international concern. The threat to public safety and security posed by some form of nuclear terrorism is not new and awareness of the terrorist threat to nuclear facilities existed even before 9/11. But in the wake of recent highly organized terrorist attacks in different countries, it is recognized that new and stronger measures must be taken to protect against and prepare for a diverse range of terrorist attacks. These upgrades focused on vehicle control measures, personnel reliability checks, requirement of armed security at sites, provision of appropriate delay and engagement barriers, and tactical response training. Although responsibility for establishing and operating a comprehensive physical protection system for nuclear materials and facilities within a state rests entirely with the government of that state, it is not a matter of indifference to other states whether and to what extent

[81]NRC "Summary of incidents that May have Involved deliberate acts directed Against Plant Equipment in Vital Areas of Operating Reactor (1980-82), " Attachment to letter from then NRC Chairman Nunzio J Palladino to congressman Edward J Karkey, February 7, 1983.

[82]NRC "Summary Of Incidents That May Have Involved Deliberate Acts Directed Against Plant Equipment In Vital Areas Of Operating Reactor (1980-82)," Attachment to letter from then NRC Chairman Nunzio J Palladino to congressman Edward J Karkey, February 7, 1983.

[83]Daniel Hirsch; The Truck Bomb and Insider Threats to Nuclear Facilities; Nuclear Control Institute, Washington, D.C. [http://www.nci.org/g-h/hirschtb.htm].

[84] Daniel Hirsch; The Truck Bomb and Insider Threats to Nuclear Facilities; Nuclear Control Institute, Washington, D.C. [http://www.nci.org/g-h/hirschtb.htm].

that responsibility is fulfilled. Physical protection has therefore become a matter of international concern and co-operation.

IAEA INFCIRC/225 titled "The Physical Protection of Nuclear Material and Nuclear Facilities" provides necessary guidance to Member States regarding requirements for physical protection against sabotage of nuclear power plants and other facilities. It also underscore that states should determine the level of protection needed against such sabotage depending upon the degree of radiological consequences. The details of these requirements are:

a. Identification and protection of vital areas – to identify and apply physical protection measures to areas which contain equipment, systems or devices, or nuclear substances where sabotage could directly or indirectly lead to unacceptable radiological consequences.
b. Access control - minimum access to and the number of access points into the protected area and vital area(s).
c. Predetermination of trustworthiness - to require unescorted employees to have a security clearance or an authorization appropriate to their level of access.
d. Vehicle search and forceful intrusions - to check the vehicles and take measures to reduce the risk of forced vehicle penetration into a nuclear facility.
e. Tampering of equipment and records - to detect tampering or interference with equipment system or devices and take special precautions during and following shutdown or maintenance.
f. Placement security guards - to establish an armed response force available at all times and capable of making an immediate and effective intervention to counter threats to nuclear facilities.
g. Contingency planning, drills and exercises - to test physical protection systems through regular drills, and develop and exercise contingency plans to manage anticipated security related emergencies.
h. Detecting equipment - to maintain the operation of alarm systems, alarm assessment systems, and the various essential monitoring equipments in the security monitoring room.
i. Communication system – to consistently communicate within and outside the facility.[85]

Consequences of Terrorist Attack

The classical illustration of the possible consequences of serious accidents at nuclear infrastructure facilities is the disaster at the Chernobyl nuclear power plant. Of course, the scale of an accident at any research reactor would be considerably smaller, but even in this case a considerable number of people could fall within its sphere and be subject to marked radiation effects and particularly profound psychological effects, which is what terrorists mainly gamble on.[86] The consequences of an attack on a research reactor are likely to be less serious than those associated with an attack on a large

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[85]The Physical Protection of Nuclear Material and Nuclear Facilities; [http://www.iaea.org/publications/documents/infcircs225r4c/rev4_sabotage.html].
[86]Russian Commentary Examines Risks of Terrorist Attacks on Research Reactors; [http://www.sgpproject.org/Personal%20Use%20Only/RUBelous.html].

power reactor. The spent fuel from research facilities typically has lower burn-up and fewer fission products than that contained in power reactors, which means that the potential harm from exposure is reduced proportionately. Moreover, research reactors operate with much less radioactive and fuel material and in the event of a successful terrorist attack are unlikely to suffer a catastrophic fuel failure or "melting," which further reduces the potential for a major radiation release. However, research reactors and industrial and medical sources are softer targets than nuclear power facilities—a factor that heightens the potential for a successful attack against, or the theft of materials from these sites.

The consequences of a successful attack on a nuclear facility would depend on a variety of factors. The size and nature of the release is known as the 'source term'. This would in turn depend on factors such as the extent of the damage and the physical and chemical properties of the materials released. Fresh fuel will contain fewer radioactive fission products than fuel nearing the end of its lifetime. The movement of radioactive material through the environment and its uptake by the human body is also a factor; weather conditions would greatly influence the distribution of radioactive material. A third factor is the efficiency of countermeasures put in place to protect people from radiation, e.g. restricting food and water supplies, sheltering, or evacuation. A final factor is the area over which environmental decontamination measures were implemented.[87]

Protective Measures

Every sort of disaster, natural or man-made, is unique and carries with it incredible challenges. If an attack on a nuclear facility is successfully carried out, society will be faced with medical, psychological, social, political, economic, and organizational challenges. A horrific attack on a nuclear facility may leave lasting psychological scars, even with only a minor radiological component. However, the following immediate countermeasures may be taken to protect the public from harmful effects of radiation:

- Shielding
- Access controls
- Sheltering
- Evacuation
- Administration of potassium iodide
- Decontamination and
- Interdiction of food sources and water supplies
- Late-Phase counter measures[88]

PAKISTAN'S RESPONSE TO NUCLEAR TERRORISM

The Pakistan Nuclear Regulatory Authority (PNRA) is empowered to control, regulate and supervise all the matters related to civil sector nuclear safety and radiation protection in Pakistan. It is the

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[87] Terrorist Attacks on Nuclear Facilities, July 2004 Number 222, [http://www.parliament.uk/documents/upload/POSTpn222.pdf].

[88] NCRP Report No. 138; Management of Terrorist Events Involving Radioactive Material.

leading Agency for ensuring that national preparedness for nuclear and radiological accidents is maintained by the operating organizations or licensees. It is also the point of contact for international agreements and collaborations concerning nuclear and radiological emergencies. In the light of the current wave of terrorism, the PNRA has taken the necessary steps with the help of licensees to strengthen the safety and security of its civil nuclear installations. In this regard the Federal Government has tasked the PNRA with the physical protection of nuclear and other radioactive material. The PNRA initiated towards the last quarter of 2006 a five year National Nuclear Safety and Security Action Plan (NSAP) to establish a more robust nuclear security regime. It seeks capacity building in Pakistan’s ability to plan for, respond to, and recover from terrorist incidents in collaboration with relevant governmental agencies. The plan has wide area of applications related to radiation sources, transport safety, deployment of radiation detection equipment widely, etc. In addition to the above, the following steps have been established to further enhance the safety and security capabilities of nuclear installations.

Establish a PNRA Nuclear Safety and Security Training Centre

The PNRA is the focal point of training in nuclear safety and security. This Centre has established laboratories with appropriate state-of-the-art equipment and deputed about six officers and supporting staff for the smooth functioning of the Center.

To start, a few select senior PNRA staff have been trained in appropriate institutions and centers in collaboration with the IAEA under the Train the Trainer Program of the PNRA senior persons for sustainability of system. They are responsible for developing the training modules for the Centre and establishing its needed infrastructure. They are educating trainers, having a “multiplier” effect. Junior officers of PNRA are being trained in source identification, locating and recovering techniques. Personnel from external agencies having the role as first responders and expected to deal with nuclear and radiological emergencies are being trained in the identification and handling of radioactive sources as well as emergency management skills. The Centre is continuously facilitating this training throughout Pakistan due to the significant rotation and redeployment of first responders. Additionally, the Centre is providing consolation and evaluation to licensees. Further, the Centre has a research role in techniques and technologies in nuclear safety and security.

The center is training the personnel from customs, border forces, etc. in the area of detection of nuclear and other radioactive materials at international borders. So far the center has arranged about seventeen training courses in the areas of detection of nuclear and other radioactive materials at borders and response to unauthorized acts involving nuclear and other radioactive materials. About 430 personnel have been trained so far.

Establish National Nuclear Security Emergency Co-ordination Centre

A National Nuclear Security Emergency Co-ordination Centre (NuSECC) has been established to assess, respond and co-ordinate in case of a nuclear security emergency at the national level. It will track all movements of high risk category radioactive sources in Pakistan. The centre is manned 24 hours a day with at least six officers and support staff. It is establishing six mobile monitoring laboratories to be distributed and located at each of the Regional Directorates and Inspectorates. The center has been established at Islamabad and being manned around the clock. The center will provide the necessary expert opinion through a Mobile Emergency Support Team (MEST) at regional offices or at HQ. This center has arranged a number of tabletop and field exercises for first responders, law enforcement agencies, intelligence agencies, medical responders, and others to respond in case of a malicious act involving radiological dispersal devices (RDD).

Global Initiative to Combat Nuclear Terrorism

Pakistan has joined recently in the "Global Initiative to Combat Nuclear Terrorism" which was jointly launched by US President George W. Bush and Russian President Vladimir in July, 2006. Participation in this Global Initiative will be helpful to improve national capabilities to combat nuclear terrorism by sharing state of the art knowledge with member countries in this area.

RECOMMENDATIONS

The following recommendations are presented for strengthening infrastructure against sabotage and coping with situations involving nuclear terrorism:

- **Physical Protection Measures:** The PNRA with the help of licensees has taken stringent measures such as provision of physical barriers, access control, installation of detection equipment, personnel reliability checks, etc. Besides these considerations, preplanning and intelligence gathering are very important through well developed and coordinated efforts of various agencies to deter, detect and thwart possible sabotage attempts[89]. The agencies should keep track of terrorist groups, their financial resources, linkages with the outside world, and potential to engage in nuclear terrorism.

- **Personnel Reliability Program (PRP):** A personnel reliability program is an integral part of any nuclear security infrastructure. The elements of PRP have been described as several lines of inquiry to develop a comprehensive picture of the individual in question. A background check is conducted to verify identity, credit history, criminal history, reputation and character. Psychological and medical screening are used to evaluate the mental health and stability of the individual; depression, schizophrenia, epilepsy, high/low blood pressure and other disorders are all taken into consideration. Additionally, a detailed interview to verify background information and elucidate other potential concerns is conducted at the time of employment or when a sensitive task is being assigned. Periodic reviews of job performance and coworker interaction are a standard means of ensuring that an employee’s reliability remains high over time, and an individual’s after work activities may also be monitored. The following occurrences may result in decertification for nuclear duty: alcohol abuse/dependency, drug abuse, conviction of or involvement in a serious incident, an adverse medical, physical or mental condition or serious progressive illness, lack of motivation, or suicide attempt or threat.[90]

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[89] NCRP Report No. 138; Management of Terrorist Events Involving Radioactive Material.

[90] Personnel Reliability Programs, Ryan Crow, Project Performance Corporation, 1760 Old Meadow Road, 4th Floor , McLean, Virginia, 22102 , 703-748-7000; [http://www.ppc.com/modules/knowledgecenter/prp.pdf] and references therein.

- **National Radiation Emergency Coordination Centre (NRECC) and Emergency Plans:** As a national nuclear regulator, PNRA is responsible to coordinate and ensure all the activities for preparedness and response to nuclear or radiological emergencies. PNRA's NRECC, an emergency response coordination center is manned around the clock to receive national as well as international notifications regarding events related to nuclear or radiological incidents and assist in national emergency response activities. As already stated, NuSECC is responsible to assess, respond and co-ordinate in case of a nuclear security emergency at the national level. It has been planned that NuSECC being part of NRECC will develop capabilities to deal with incidents like malicious acts, sabotage, acts of nuclear terrorism on nuclear installations. After the devastating earthquake of October 8, 2005 in Azad Kashmir and North West Frontier Provinces, the Prime Minister of Pakistan approved the establishment of a National Disaster Management Commission and Authority (NDMC & NDMA) for quick response to all kinds of natural and manmade disasters. The NDMA is responsible to coordinate with relevant federal and provincial departments, district governments, and Army and civil defense to implement national emergency response plans. The PNRA has developed coordination with NDMA in order to interact with appropriate stakeholders for continual improvement of emergency preparedness capabilities at all levels. The Centre, in coordination with NDMA, should have capabilities for emergency assessment and diagnosis of the sabotage event, for management, response, hazard mitigation and for advice on evacuation or shelter options.

- **Emergency Exercises:** Decision makers need to know what steps are to be taken for coping with an act of terrorism at nuclear facilities, the PNRA needs to be present at the table with the decision makers, local leaders need to be in direct contact with national leaders, and the most important lesson is that all the systems must be exercised regularly. In pursuance to national regulations, licensees are obliged to prepare and submit emergency plans, one On-site and another, Off-site, for their facilities. These plans are reviewed and approved by the PNRA. The adequacy of these plans is demonstrated through periodic, partial and integrated drills and exercises which are observed and evaluated by PNRA personnel in coordination with the PNRA's regional offices. Findings, along with recommendations, are conveyed to licensees for implementation.

- **Training and Exercises of Responders:** All emergency responders are undergoing initial training at levels corresponding to their role that they are expected to perform during a nuclear or radiological incident. The PNRA conducts regular table top and field exercises for first responders including emergency medical services, fire fighters, rescue services and intelligence agencies, etc. "The overall nuclear and radiological training objectives for emergency responders are: 1) to enhance their ability to take appropriate measures to protect themselves and the public, and 2) to increase their confidence about effectively managing an emergency involving radiation or radioactive materials".[91]

[91]NCRP Report No. 138; Key Elements of Preparing Emergency Responders for Nuclear and Radiological Terrorism.

- **Equipment for Radiation Detection and Personal Protection:** Additional equipment and supplies would be required for detection of radiation, to screen large numbers of individuals for contamination at the scene, and to screen for initial decontamination needs at emergency facilities (designated reception centers and hospitals).[92]

- **Planning for Radiological Protection:** Planning for radiological protection in the aftermath of an event would be required for the establishment of appropriate programs at both the local and national level. These programs need to ensure that first responders and rescuers are adequately trained and have the proper equipment to identify the presence of radiation and radioactive contamination, and that radiation protection specialists are available to advise local and other relevant authorities.[93]

- **Robust e-Communication:** Robust and direct electronic communication is needed in the PNRA to share information between federal/provincial/local officials and the licensee for preventing and mitigating the effects of a terrorist attack.

- **Credible Information:** It is imperative that clear communications be established with the public regarding an incident. The public should be informed about the incident as soon as possible. In this regard, there is a need for a designated, credible spokesman that can deliver a statement shortly after with real time information with all concerned agencies.

- **Crisis Management:** A crisis management team to handle a situation as well as to pre-plan and organize to possibly deter another event at unknown location is needed.

- **Public Education:** In order to minimize confusion and chaos, it is necessary to create public awareness about the potential effects of nuclear terrorism. This involves integrating the official and unofficial media to disseminate information and encourage public confidence without causing unnecessary panic. The use of the civil defense warning sirens and loud speakers at mosques may be used to alert people and to advise them to check the radio or television for further information.

- **Sheltering and Evacuation:** In case of successful terrorist attack on a nuclear facility, the population affected by the release and dispersion of radioactivity, that will requiring shelter or even evacuation will depend on the prevailing weather conditions. Sheltering may provide protection that is equal to or greater than evacuation, taking into consideration such factors as weather, competing events, fast-breaking or short-term release, or traffic considerations. As an example, during a relatively short term release, it may be prudent to recommend that the population shelter in place, such as at home, the office, school, or shopping mall. Depending on the type of building, sheltering can result in a radiation dose reduction of up to 80%

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[92] NCRP Commentary No. 19; Key Elements of Preparing Emergency Responders for Nuclear and Radiological Terrorism.

[93] Health Physics; The Radiation Safety Journal, Vol. 89, No. 5, November 2005.

compared to being outdoors.[94] However, advice from the authorities to shelter and evacuation on the basis of national emergency reference levels might lead to a panic situation prompting a mass self-evacuation. If the public undertakes self-action, particularly self-evacuation, many more persons are likely to be on the streets without much protection and/or in poorly shielded vehicles and, indeed, some of which may unknowingly move into contaminated areas becoming trapped for hours in the traffic jams and chaos that are almost certain to arise. In such circumstances, the public may receive a greater radiation exposure than if, generally, they remained indoors sheltering. Therefore, unless adequate infrastructure is in place, sheltering or evacuation directives may be counter productive effects.

- **Use of Iodine Prophylaxis (Potassium iodide):** Potassium iodide, if taken in time, blocks the thyroid gland's uptake of radioactive iodine and thus could help prevent thyroid cancers and other diseases that might otherwise be caused by exposure to airborne radioactive iodine that could be dispersed in a nuclear disaster.[95]

- **Medical Response:** Medical treatment will be required for the individuals who have received a significant whole-body exposure, and also for those who have inhaled radioactive material or who have wounds involving radioactive materials.

- **Decontamination Technologies:** The most damaging impact from most radiological attacks will be the contamination of the environment, buildings and land. Necessary decontamination technologies will be required immediately.[96]

- **Late Phase Decision Making:** The late phase response will include cleaning up the area and restoring it to a preexisting condition. The area to be restored may quite large as will the cost and effort required to accomplish these tasks. Factors such as total cost, time to accomplish the tasks, risks associated with the cleanup criteria, etc. will be important parameters in such a decision-making process.[97]

CONCLUSION

The advancement in the knowledge of science and technology and their accessibility to terrorists has made the threat of nuclear terrorism no longer a fiction but real with their intention to inflict catastrophic damages to man, environment, and property. In the presence of multiple safety and physical barriers, the probability of nuclear terrorism on research reactors is very low. However, even after a successful sabotage act on a nuclear research reactor, the extent of damage both to public and

[94]Frequently Asked Questions about Emergency Preparedness and Response; [http://www.nrc.gov/about-nrc/emerg-preparedness/faq.html].

[95]Potassium Iodide, Anti-Radiation Pill FAQ & Iodine Tablets, Pills, Sources; [http://www.ki4u.com/#1]

[96]NCRP Commentary No. 19; Key Elements of Preparing Emergency Responders for Nuclear &Radiological Terrorism.

[97]NCRP Report No. 138; Management of Terrorist Events Involving Radioactive Material.

environment will depend upon the mode of attack, the quantity of radioactivity release, the movement of radioactive material through the environment and its uptake by the human body, weather conditions, time of attack, the efficiency of countermeasures put in place to protect the public from radiation, and many other factors. However, as a result of such attack, it is suspected that there will be widespread environmental contamination. Difficulties are likely to arise in informing members of the public in the surrounding rural areas where individuals may be unaware of the incident and who, scattered about the countryside, may be difficult to locate and advise in time. However, the people living in an urban area would be informed to restrain themselves in home in order to avoid themselves from harmful effects of radiation. All exposed individuals will need to be monitored for health outcomes over their lifetimes, especially those that suffer internal contamination. Massive decontamination efforts would be needed for recovery and if decontamination remains unsatisfactory, institutional controls would become essential. To dilute the consequences of any successful sabotage event, preplanning is very important through well developed and coordinated efforts of various agencies. Periodic integrated table-top and field exercises based on credible scenarios developed on the basis of intelligence information gathering should remain the focus at all levels.

The controls around various nuclear installations and radiation facilities in Pakistan are enough to deter and delay a terrorist attack and any malicious diversion would be detected in early stages. The paper is an attempt to provide information about the research reactors, barriers available for their protection, various modes of nuclear terrorism, measures that can be taken to reduce their probability of happening and to cope with such scenarios. Therefore, it can be concluded that the fabrication of a sabotage act on nuclear facilities is not very attractive to a terrorist group in general and specially within the context of Pakistan.

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