Nuclear Terrorism

fact sheet 10

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French Atomic Bomb Test, Mururoa Atoll, South Pacific in 1994: AAP Image/AP

Nuclear terrorism could take many forms. Nuclear power plants are attractive terrorist targets.

A 'dirty' bomb spreading radioactivity is simple and likely. If they were able to obtain highly enriched uranium or plutonium, building a nuclear bomb is within the capabilities of a well-organised terrorist group.

Many nuclear facilities and materials are not secure. Nuclear weapons and fissile material should be comprehensively and urgently secured before being abolished.

Two of the main dangers inextricably associated with nuclear reactors are nuclear proliferation and nuclear terrorism. Terrorism involving nuclear weapons or radioactive materials could take a wide variety of forms. Terrorists could:

- Steal, buy or otherwise acquire fissile material and fabricate a crude nuclear bomb.
- Steal, buy or otherwise acquire a ready-made nuclear weapon; or take over a nuclear-armed submarine, plane or base.
- Attack a nuclear reactor or waste fuel cooling pond.
- Disrupt critical inputs for the safe running of a nuclear reactor eg water supply for cooling, electrical power supply systems.
- Attack or steal nuclear fuel or waste containers, most likely in transit.
- Make and detonate a radiological weapon, or 'dirty bomb', to spread radioactive material.

All of these have the potential to cause deaths and injuries on a scale from hundreds to hundreds of thousands or more; large-scale fear, panic, social and economic disruption; long-term radioactive contamination and massive clean-up costs. The risks of all of them will increase if more nuclear facilities and reactors are built.

Terrorists and nuclear terrorism

In 1996, the highest international legal authority, the International Court of Justice, concluded that "the threat or use of nuclear weapons would generally be contrary to the rules of international law …".[1] Nuclear weapons are weapons of terror,[2] and any use or threat of nuclear weapons constitutes terrorism, whether by governments or non-state groups, however it is justified.

Attacks such as the PanAm jumbo jet bombing over Lockerbie, Scotland in 1988; the Aum Shinrikyo nerve gas Tokyo subway attacks in 1997; the simultaneous New York World Trade Centre and Pentagon attacks in 2001; and the multiple bombings of commuter trains in Madrid in March 2004, required considerable skill and coordination. Building a crude nuclear explosive would require no greater technical skill than was involved in making the Lockerbie bomb or Tokyo nerve gas weapon.

Some terrorist groups now have access to professional scientific and technical skills, large sums of money, international networks, modern communications, and a burgeoning supply of recruits. Aum Shinrikyo and al Qaeda are the two most capable and well-financed terrorist groups thus far known to have pursued nuclear weapons. While it appears this goal has not yet been achieved, if it were able to obtain fissile material, a nuclear explosion is within the capabilities of a well-organised terrorist group.[3]

Building a terrorist bomb

The most difficult part of constructing a nuclear weapon is obtaining the fissile material required – either highly enriched uranium (HEU, enriched to 20% or more of the isotope U-235) or plutonium (Pu). There is an important distinction between the skills needed to build reliable, efficient, compact, sophisticated nuclear weapons with predictable yield, able to be delivered by a missile or fighter plane; and building one or a few crude nuclear weapons which may be bulky, unsafe, of uncertain yield, and require delivery by boat or truck; but nevertheless have a high probability of exploding. Designs for reliable nuclear weapons are openly available and building them repeatedly proven to be well within the capacity of competent undergraduate physics students.

The weak radioactivity of uranium means it can be handled by hand and is easily smuggled. A further possible advantage for terrorists is that the simplest gun-type bomb design can be used, in which one subcritical mass is fired (or even dropped) down a cylinder into another subcritical mass, the combined mass being supercritical ie able to sustain an explosive chain reaction. The bomb dropped on Hiroshima, and South Africa's now dismantled nuclear weapons, were of this type. Sufficient HEU for such a weapon could easily fit within a 5 litre container. However, enrichment of uranium is technically demanding and current centrifuge methods involve large, expensive industrial-scale facilities. Laser enrichment, such as being developed at Lucas Heights in Sydney by Silex Systems, now in partnership with General Electric Corporation, if further developed, could pose a significant proliferation risk by making uranium enrichment simpler, cheaper, more compact, modular and concealable.[4]

Plutonium isotopes are inevitably produced when U-238 (the main isotope in natural uranium) absorbs neutrons in a nuclear reactor. All plutonium isotopes (Pu-238, 239, 240, 241, 242) are fissionable and though weapons are typically made with weapons-grade plutonium enriched to more than 90% Pu-239, any combination of plutonium isotopes containing less than 80% Pu-238 is usable for making a nuclear weapon, including so-called reactor-grade plutonium.[5] Spent nuclear fuel must be chemically reprocessed to extract the plutonium before the latter can be used in weapons; this process is relatively straightforward but is made much more difficult by the intense radioactivity produced by the other fission products in spent reactor fuel. Plutonium is more radioactive, easier to detect and somewhat harder to handle than uranium; but terrorists could handle it with simple equipment such as rubber gloves and polyethylene sheeting.

Nuclear weapons using plutonium must use an implosion design, with a series of shaped explosive lenses arranged in a sphere, fired simultaneously to compress a less than critical mass of plutonium (or HEU) at the centre. While this is technically more demanding than construction of a gun-type bomb, it is certainly within the capacity of a sophisticated terrorist group, particularly if they obtained knowledgeable help, as al Qaeda has been attempting.[6]

The critical mass of fissile material is not fixed, but decreases with the square of the density ie if squeezed to twice its normal density, only a quarter as much material is needed. If a sphere of plutonium metal is surrounded by a shell of neutron reflecting material such as beryllium or uranium, which reduces the number of neutrons escaping without causing a fission event, the critical mass can be reduced further. A thick reflector will reduce the critical mass by a factor of 2 or more (Table 1). Thus whereas the critical mass of a bare sphere of weapons grade plutonium metal is about 11 kg, modern nuclear weapons contain less than 4 kg of plutonium. Six kg of weapons-grade plutonium, the amount used in the bomb dropped on Nagasaki, would occupy less than 400 mL, about the size of an ordinary drink can or a grapefruit.

Both HEU and plutonium are best suited to bombs in pure metal form. In the nuclear industry, material is often in oxide form, however these can be converted to metal through chemical processes which have been widely published. One worrying potential source is HEU used to fuel research and medical isotope production reactors – in 2004 there were 128 such facilities worldwide. Switching all such facilities to run on low enriched uranium (as the new Opal reactor at Lucas Heights does) is practical and highly desirable. These facilities often have quite limited security provisions, and research reactor fuel elements are typically small and easily handled. The chemistry to separate the uranium from such fuel is roughly similar in complexity to that involved in making heroin from opium poppies, also an interest of al Qaeda. Spent fuel from research reactors also poses a serious proliferation risk of being stolen and processed for bomb manufacture.

Table 1. Fissile material requirements for fission nuclear weapons.[7]

	Weapons-grade Plutonium (kg)		Highly enriched Uranium (kg)	
	Technical capability		Technical capability	
Yield (kt)	Low	High	Low	High
1	3	1	8	2.5
20	6	3	16	5

Terrorists would need to buy or steal HEU or Pu, or a ready-made nuclear weapon. This is a real danger: the global stockpile of HEU and Pu currently amounts to 2300 tons, enough for more than 200,000 nuclear weapons.[8] These materials exist in hundreds of buildings in more than 40 countries, under security arrangements ranging ‘from excellent to appalling’.[9]

There have been numerous instances of nuclear smuggling. The IAEA Illicit Trafficking Database has documented more than 650 instances of intercepted smuggling of radioactive materials over the past decade; 18 cases of seizure of stolen Pu or HEU have been confirmed. Some examples include:[10],[11]

- 40 kg of weapons grade uranium seized in Odessa in Dec 1993.
- Czech police seized 4 kg HEU in Dec 1994, the same year German police seized more than 400 g Pu arriving from Moscow.
- Turkish police arrested 2 men with 1.16 kg weapons-grade uranium in Oct 2001; the same month the Russian Ministry of Defence reported 2 recent terrorist attempts to break into nuclear storage sites.

- Russian police arrested a foreman of the Elektrostal nuclear fuel fabrication facility and co-conspirators for stealing 22.2 kg LEU in April 2006 (the same facility processes large amounts of HEU).[12]

The precise number of Russian nuclear weapons is not known,[13] and in 1996 former Russian presidential National Security Adviser Aleksandr Lebed claimed that more than 80 Russian suitcase nuclear bombs were unaccounted for. The veracity of this claim is uncertain, but the possibility that one or more Russian weapons are missing is real. Former CIA Director Porter Goss told the US Congress in 2005, "There is sufficient [Russian] material unaccounted for so that it would be possible for those with know-how to construct [a] nuclear weapon." But as of 2005, only 54% of the buildings in the former Soviet Union holding nuclear material had received comprehensive security upgrades.[14]

IAEA Director General ElBaradei estimated in March 2006 that regarding protection of nuclear material, "… perhaps 50 per cent of the work has been completed."[15]

Exploding a stolen nuclear weapon

Many modern nuclear weapons have safety features intended to minimise the risk of unauthorised detonation - such as electronic locks known as permissive action links, limited try features, and mechanisms to prevent detonation unless the weapon has been subjected to an expected launch-to-target sequence such as acceleration followed by free flight. However these may be lacking for older, particularly Soviet tactical, weapons. Although many such older weapons may no longer be deployed, neither Russia nor the US has made any commitment to destroy all of them. China, India and Pakistan are not believed to incorporate optimal modern safety features in their weapons, though many of these are thought to be stored partly dissembled. If they could not work out how to detonate a stolen weapon(s), terrorists might remove the fissile material and use it to make a crude or dirty bomb.

Attacking a nuclear reactor or spent fuel storage facility

Currently 441 nuclear power plants operate in 31 countries. Nuclear power reactor cores typically contain 20 to 40 times the amount of radioactive materials as would be released by a 'small' kiloton range nuclear bomb such as described below. The most likely terrorist targets are the reactor itself and the ponds storing the spent fuel.

An attack on a reactor could cause the core to go super-critical (as happened during the 1986 Chernobyl disaster), or cause loss of the coolant that removes heat from the core (as happened during the Three Mile Island accident). Spent fuel elements are normally kept in storage ponds, usually close to the reactor, for 5-10 years under around 3m of water before being stored in a repository, or reprocessed to separate out the plutonium which is inevitably produced. The ponds are attractive terrorist targets for two reasons: the buildings housing them are typically like warehouses, without the hardening and multiple layers of containment a reactor should have; and they often contain very large amounts of long-lived radioactive materials – typically 10-20 times the amount of radioactivity as in the reactor core.

Terrorists aiming to achieve criticality or loss of coolant, or both, could target a reactor or spent fuel pond by any of the following:

- A truck or light aircraft carrying high explosives exploded near a critical part of the facility.
- Crashing a highjacked commercial airliner into the reactor building or spent fuel pond.
- Attacking the facility with small arms, artillery or missiles and occupying it.
- Using infiltration or insider sabotage.
- Disrupting the power or water supply to the reactor.
- Draining water from the spent fuel ponds.

Any of these could lead to massive release of radioactivity. Since the 11 Sep 2001 terrorist attacks in the US, the IAEA, US Nuclear Regulatory Commission (NRC),[16] and UK Parliamentary Office for Science and Technology have all stated that no reactors are built to withstand the impact of a large commercial aircraft.[17] Throughout the 1990s, despite months of advance warning and increased security, 47% of US nuclear power plants failed to deter small mock terrorist attacks conducted by the NRC.[18] As early as 1982, an US Argonne National Laboratory study showed that even if only 1% of a jetliner's fuel penetrated a reactor's containment wall and ignited, this would create an explosion equivalent to 450 kg of dynamite, with simultaneous failures in key safety systems, unstoppable loss of reactor coolant, and nuclear fuel meltdown.[19]

The world may already have been very close to such an event. The fourth hijacked airliner on 11 Sep 2001 was heading directly for and no more than 15 minutes flying time away from the Three Mile Island nuclear power plant when it crashed in a Pennsylvania field, as passengers and crew apparently fought the hijackers.

Non-state attacks on nuclear plants, thus far without radioactive release, have occurred; and more threatened. Examples include:[20]

- March 1973: guards at a nearly completed nuclear power reactor at Lima, Argentina were overpowered in an attack by 15 armed men.
- Dec 1977: 4 Basque terrorist detonated bombs which damaged the reactor vessel and steam generator, killing 2 workmen, at a nuclear power plant under construction in Arminza, Spain.
- Jan 1982: 4 antitank rockets were fired at the nearly-completed Superphenix fast breeder reactor at Creys-Malville, France, damaging the containment vessel.
- Dec 1982: ANC fighters detonated 4 bombs inside a nuclear power reactor under construction at Melkbosstrand, the Cape, South Africa.

States have also attacked nuclear facilities including reactors:

- Iraq's nuclear facilities were bombed by Iran during the Iran-Iraq war 1980-88; in 1981 Israel bombed the nearly-completed Osirak reactor; and Iraqi nuclear facilities were attacked by the US in 1991 and 2003.
- A nuclear plant in Iran was targeted by Iraq in the 1980s.
- Iraq claimed to have targeted Israel's Dimona nuclear reactor with Scud missiles in 1991.

Even unarmed environmental groups have been readily able to demonstrate the vulnerability of nuclear plants eg Greenpeace activists scaled the Sizewell reactor in the UK, and others similarly accessed the reactor complex at Lucas Heights in Sydney. Attacks could also, alone or in combination, target more peripheral but important components of a nuclear plant's operation, such as the switchyard, cooling towers or cooling water conduits, or plant safety systems, such as emergency diesel generators. In a pressurised water reactor, core meltdown could occur within less than 1 minute after loss of coolant; with other types of reactor it might take a few minutes.[21]
Nobel laureate nuclear physicist Joseph Rotblat demonstrated 25 years ago the dangers posed by conventional or nuclear attack on nuclear reactors.[22] The decay of radioactivity of a nuclear reactor is much slower than that following a nuclear explosion, because of a greater inventory of long-lived isotopes. An attack on a nuclear reprocessing plant or fuel storage tank would result in even greater and longer-lived radioactivity release than following an attack on a reactor (Table 2).

Table 2. Areas affected by detonation of nuclear weapons alone and on nuclear power facilities.[23]

Radiation dose between 1 month and 1 year after detonation (Gray)	Area (square km) 1 Mt bomb	1 Mt bomb on a 1000 MW reactor	1 Mt bomb on a spent fuel storage tank
1	2000	34,000	61,000
0.1	25,000	122,000	164,000

Mt –million tons TNT equivalent explosive power; MW – million watts electricity output; 1 Gray is a substantial radiation dose, often resulting in acute radiation sickness; 0.1 Gy (100 mGy) is equivalent to 100 times the recommended annual dose limit for a member of the public, about 1000 chest Xrays, or about 40 years of natural background radiation

Thus even without the use of nuclear weapons, targeting of operating nuclear reactors and/or associated fuel storage or reprocessing facilities could essentially convert a war to a nuclear war, and a conventional terrorist attack into a nuclear attack.

Detonating a radiological weapon or 'dirty bomb'
This is the simplest terrorist nuclear device, not involving a nuclear explosion. It would most likely be detonated in a major urban centre, and consist of conventional high explosive (eg. semtex, dynamite or TNT) surrounded by incendiary material such as thermite, with radioactive material at the centre. The fire ignited by the incendiary material would carry the radioactivity up into the atmosphere to be dispersed downwind. Many types of radioisotopes could be used – from a terrorist perspective, preferably relatively easily available, energetically radioactive, with a long half-life. Suitable candidates include Cesium -137, Cobalt-60, Iridium-192, Strontium-90 and plutonium. Plutonium would cause greatest harm but is difficult to acquire. Highly radioactive material with long-lived isotopes, such as spent nuclear fuel, and large quantities, could significantly increase adverse health effects.

There are literally millions of radioactive sources used globally in industry, medicine and agriculture; in medicine, the most powerful radioactive sources are used for radiotherapy for cancer. Many of these sources could be used for a dirty bomb; and many are not kept securely. Even in industrialised countries where security is reasonably strong, thousands of radioactive sources have been lost or stolen.

Consequences of nuclear terrorist scenarios

A nuclear explosion in a major urban centre
A 12.5 kiloton bomb (a little smaller than the Hiroshima bomb) smuggled on a cargo ship into New York City, according to US government analytical tools, is estimated to cause:[24]

- 52,000 immediate deaths from heat and blast.
- 238,000 people exposed to direct radiation, of which 10,000 would die and 44,000 would suffer acute radiation sickness.
- 1.5 million people would be exposed to radioactive fallout in the following few days – in the absence of effective evacuation or sheltering this could kill an additional 200,000 people and cause hundreds of thousands to suffer acute radiation sickness.

The US Dept of Homeland Security estimated in 2005 that a 10 kt nuclear explosion in Washington DC would kill 15,000 and injure 31,000 from blast; kill 190,000 and injure 264,000 from short-term radiation exposure; and cause 49,000 cancer cases, 25,000 of them fatal, from long-term radiation exposure downwind.[25]

An attack on a nuclear power plant or spent fuel storage ponds
Such an attack could be catastrophic, because of the large amounts of long-lived radioactive materials such facilities contain. A 2006 study of a scenario in which a hijacked jet crashes into the Braidwood Nuclear Power Plant outside Chicago estimated that more than 7.5 million people would be exposed to more than the maximum allowed annual population radiation dose (1 mSv), of which 4.6 million would receive more than the maximum allowed annual occupational radiation dose (50 mSv), more than 200,000 would develop radiation sickness and 20,000 might receive a lethal dose.[26] Social and economic consequences and clean-up costs would be massive.

A meltdown at the Indian Point power plant north of New York City has been estimated to result in 44,000 radiation deaths within 1 year and 518,000 excess cancer deaths over time. Millions of people in the greater New York City area would have to be permanently relocated, huge areas would be uninhabitable for many years, and economic losses could be over US$2 trillion.[27]

An explosion involving liquid spent reactor fuel at the Sellafield plant in the UK, one of the facilities where Australian-origin spent reactor fuel is reprocessed, which released either 17% of the high level liquid waste, or less than 1% of the plutonium (about 200 kg) would be approximately 10 times as devastating as the Chernobyl disaster and would require evacuation of an area which could include Newcastle or Manchester, depending on wind direction.[28]

A radiological weapon or dirty bomb
The main immediate casualties of a dirty bomb would be related to the conventional explosive, and are likely to number in the tens or hundreds. Depending on the nature and size of the bomb and where and when it was exploded, thousands, tens of thousands, or potentially hundreds of thousands could be exposed to radiation and

live with an increased risk of cancer. Substantial fear, panic and social and economic disruption would be inevitable – the term 'weapon of mass disruption' has been used. Decontamination may need to be extensive and could be very costly, involving demolition of buildings and resurfacing of roads and pavements (cesium can bind chemically to windows, roads and buildings).

The potential disruption even conventional bombings can cause is clearly attractive to terrorists. The 3 large conventional bombs exploded by the Provisional IRA in London between 1992-6 caused estimated damages of A$5 billion and had a substantial effect on tourism and the re-insurance market.[29] The additional persistent consequences of dirty bombs could be expected to be significantly greater.

Lucas Heights – terrorist target

The nuclear complex at Lucas Heights in Sydney's southern suburbs, including the new Opal nuclear reactor licensed for operation in 2006, is arguably Australia's most attractive terrorist target. A terrorist attack with breach of the reactor containment structure or dispersal of highly radioactive spent fuel waste could cause significant radioactive fallout in Australia's largest city, causing fear and panic, major social and economic disruption, persistent environmental contamination requiring extensive clean-up, long-term health risks and massive costs.

The attractiveness of Lucas Heights as a terrorist target is evidenced by the frequency with which it is publicly known to have been the target of terrorist planning:

- 1983: 9 sticks of gelignite, 25 kg of ammonium nitrate (usable in explosives), 3 detonators and an igniter were found in an electrical substation inside the boundary fence. A detonator was set off but did not detonate the main explosives. Two people were charged.
- 1984: a threat was made to fly an aircraft packed with explosives into the HIFAR reactor; one person was found guilty of public mischief.
- 2000: in the lead-up to the Sydney Olympics, New Zealand detectives foiled a plot to attack the reactor by Afghan sympathisers of Osama bin Laden.[30]
- 9 October 2001: NSW and Federal police conducted a full search following a bomb threat directed at ANSTO.[31]
- October 2003: French terror suspect Willy Brigitte deported from Australia, held on suspicion of terrorism in France; alleged to have been planning to attack the reactor and to have passed on bomb-making skills to 2 Australians.[32]
- Nov 2005: multiple coordinated arrests of terrorist suspects in Sydney and Melbourne; court documents reveal the Lucas Heights reactor was a potential target; 3 of the 8 alleged members of the Sydney terror cell had previously been caught near the reactor facility by police in Dec 2004, each alleged to have given different versions of what they had been doing. An access lock for a gate to a reservoir in the vicinity of the reactor had recently been cut.[33]

The ease with which the Lucas Heights facility and reactor could be attacked is demonstrated by:

- 17 Dec 2001: Greenpeace action to highlight vulnerability of Lucas Heights – 21 persons climbed into the facility and displayed 'Nuclear – never safe' banners at 3 sensitive locations: the reactor building, the high level waste storage building and a radio tower; while 25 people marched into the reactor complex at 0715 on a weekday morning.[34]
- Nov 2005: a reporter and photographer were able to park a 1-ton van for more than half an hour outside the Lucas Heights back gate, protected by a simple padlock able to be cut with bolt-cutters, 800 m from the reactor and cooling towers.[35]

Conclusions

- There is a high probability that a nuclear terrorist attack will occur during the next decades. A dirty bomb attack is probably essentially inevitable.
- The US and Russia still own 95% of all nuclear weapons and materials. The massive nuclear arsenals and too often increasing readiness of states to use their nuclear weapons is the major nuclear terror.

- Ending risks of nuclear proliferation and terrorism will require comprehensively securing radioactive sources, an end to uranium enrichment and reprocessing of spent reactor fuel, abolition of nuclear weapons, and phasing out of nuclear power generation.

What can be done?

- Much remains to be done to apply the highest possible level of security to all nuclear weapons and weapons-usable material as quickly as possible.
- In 2006 the Weapons of Mass Destruction Commission recommended all states work to prevent terrorist gaining access to nuclear weapons or fissile material,[36] including by:
  - Maintaining fully effective accounting and control of all stocks of fissile and radioactive material and other radiological sources
  - Expand cooperation between countries, including sharing intelligence
  - Promote universal adherence to the 2005 International Convention for the Suppression of Acts of Nuclear Terrorism, the Convention on the Physical Protection of Nuclear Material, and UN Security Council Resolution 1540 (2004), which requires all states to develop and maintain effective physical protection measures for nuclear materials
- Use of radioactive materials should be minimised eg for food irradiation and smoke detection. Alternatives to radioactive materials should be used wherever possible. Alternatives to nuclear medicine procedures using reactor-sourced isotopes should be utilised wherever they are as good or better for patient care. Such alternatives include isotopes produced by non-reactor methods such as cyclotrons, such as for PET scanning; modern Xray techniques such CT scanning; and imaging modalities which do not involve ionising radiation, such as magnetic resonance imaging (MRI) and ultrasound.
- Production and use of HEU (in research and isotope production reactors) should cease.
- Reprocessing of spent nuclear fuel to extract plutonium (for weapons and mixed oxide fuel) should stop.
- Australia should rapidly phase out uranium mining and exports, rule out nuclear power as an appropriate or safe option, avoid other nuclear fuel chain activities such as uranium enrichment or becoming an international radioactive waste dump, make abolition of nuclear weapons a high priority, and invest massively and urgently in a benign, sustainable and renewable energy future.
- Australian government policy should ensure anti-terrorist intelligence and policing respect human rights; and much more vigorously promote measures to address causes and drivers of terrorism, including unresolved situations of dispossession, injustice and conflict such as the plight of the Palestinians; poverty and growing global inequity; militarism; and human rights abuses. It should strengthen its commitment to the UN and negotiated, multilateral approaches to global problems.

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