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Terrorist Dirty Bombs: A Brief Primer

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Abstract. Many, rightly or wrongly, fear a terrorist attack with a radiological dispersal device (RDD). RDDs may scatter radioactive material with an explosive (a dirty bomb) or other means. Radioactive atoms are unstable; as they decay, they emit electromagnetic radiation or subatomic particles that can damage cells. Many legitimate activities worldwide use radioactive material. Dealing with RDDs involves controlling sources, detecting radiation, and preparing for and responding to an attack.

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Terrorist "Dirty Bombs": A Brief Primer

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Summary

Many fear a terrorist attack with a radiological dispersal device (RDD).[1] RDDs may scatter radioactive material with an explosive (a "dirty bomb") or other means. Radioactive atoms are unstable; as they decay, they emit electromagnetic radiation or subatomic particles that can damage cells. Many legitimate activities worldwide use such material. Dealing with RDDs involves controlling sources, detecting radiation, and preparing for and responding to an attack. This report will be updated. "Nuclear and Radiological Terrorism," in the CRS electronic briefing book on terrorism, tracks developments. This report does not address nuclear power-related issues; see CRS Report RS21131, *Nuclear Powerplants: Vulnerability to Terrorist Attack.*

Technical Aspects

RDDs vs. Nuclear Weapons. In nuclear weapons, fission and fusion of certain slightly radioactive materials release energy in a huge explosion. RDDs simply scatter radioactive material; their main physical effect is contaminating an area. A terrorist group could create an RDD much more easily than a nuclear weapon.

Radiation. Most atoms are stable: they remain in their current form indefinitely. Unstable, or radioactive, atoms "disintegrate" or "decay" into other elements, mainly by emitting an alpha particle (two neutrons and two protons) or a beta particle (an electron or positron). Emission of photons (typically gamma rays, or high-energy x-rays) often accompanies decay. The emitted particles and photons are radiation. All elements have multiple isotopes, or forms with the same chemical properties but different numbers of

[1] Useful documents include Roger Eckhardt, "Ionizing Radiation — It's Everywhere," *Los Alamos Science*, no. 23, 1995, a primer on radiation; Charles Ferguson et al., *Commercial Radioactive Sources: Surveying the Security Risks*, Center for Nonproliferation Studies, January 2003; American Nuclear Society, sessions on radiological terrorism, November 2002, [http://eed.llnl.gov/ans]; U.S. Nuclear Regulatory Commission, "Medical, Industrial, and Academic Uses of Nuclear Materials," [http://www.nrc.gov/materials/medical.html]; and Gregory Van Tuyle et al., "Reducing RDD Concerns Related to Large Radiological Source Applications," September 2003 [http://www.nti.org/e_research/official_docs/labs/LAUR03-6%202.pdf].

neutrons. Each radioactive isotope decays by steps to isotopes of other elements, ending as a stable atom. While the instant when one atom will decay cannot be predicted, each isotope has a "half-life," the time for half the atoms in a mass of that isotope to decay. The faster an isotope decays, the faster it releases, and exhausts, its radiation. The radioactivity of a mass of material is measured in Curies (Ci; 1 Ci = 3.7 $\times 10^{10}$ disintegrations per second). Cobalt-60 (the number is the number of neutrons plus protons in the atom's nucleus), with a half-life of 5.3 years, is highly radioactive; uranium-235, with a half-life of over 700 million years, is not.[2] Each isotope has a unique decay fingerprint (e.g., gamma radiation energy) that can be used to identify it.

Biological Effects. Radiation strikes people constantly, but most of it, like radio waves and light, is not "ionizing": it does not have enough energy to damage cells significantly. The biological effects of ionizing radiation depend on the amount of energy deposited in the body, called the absorbed dose. Higher doses produce direct clinical effects including tissue damage, radiation sickness and, at very high levels, rapid death. With chronic low-level exposure, no clinical effects are observed, but the exposed individual may have an increased lifetime risk of developing cancer. Absorbed dose depends on several factors. Some are straightforward, such as source strength, distance, shielding, time of exposure, and energy per particle or photon. Others are more complex. *Type of radiation:* A layer of dead skin or a few inches of air stops alpha particles, more material is needed to stop beta particles, and much more is needed to block gamma rays, which are more penetrating. *Form of material:* Alpha and beta emitters do little harm outside the body because they are easily stopped. Inside the body, they can do much damage. One can with few ill effects pick up a lump of plutonium-239, an alpha emitter, because the dead skin layer stops alphas, but a speck of the same material deep in the lungs bombards tissue with alphas and can cause lung cancer. An RDD thus poses a greater health threat if its material is finely powdered — and thus more readily dispersed and inhaled — rather than granular. *Chemical behavior of the element in the body:* Certain organs concentrate particular elements. Strontium concentrates in bone; radioactive strontium-90 can cause bone cancer, breast cancer, and leukemia. The thyroid gland concentrates iodine; radioactive iodine-131 can cause thyroid cancer.[3]

Sources of Radioactive Material. Radioactive sources have many beneficial uses; millions are used worldwide. Sources with a tiny fraction of a Curie, such as household smoke detectors, do not pose a terrorist threat, but a source with even a few Curies may be of use for an RDD. While hundreds of radioactive isotopes exist, only a few isotopes, all produced in nuclear reactors, are of concern for RDDs. Isotopes of special concern, typical sources, and Curies per source, include cesium-137 (half-life 30.2 years), used in external beam radiation devices to treat cancers (13,500 Ci) and equipment to monitor wells for oil (0.027-2.7 Ci); and cobalt-60 (half-life 5.3 years), used in industrial radiography (3-250 Ci) and cancer therapy (0.0014-0.27 Ci). Such sources often have little security because they are small, have modest amounts of shielding so they

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[2] U.S. Department of Energy. Office of Environmental Management. "Characteristics of Important Radionuclides." [http://www.em.doe.gov/idb97/tabb1.html]

[3] Potassium iodide protects against radioactive iodine by saturating the thyroid with stable iodine-127; it does not protect against other elements. Terrorists are unlikely to use iodine-131 because they could obtain it only from a nuclear reactor, its half-life is so short that much of it would decay before they could use it, and its intense radioactivity makes it hazardous to handle.

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can be used in the field, and do not have enough radiation to be self-protected. They are sometimes abandoned. In contrast, terrorists would find isotopes with very short half-lives (hours or less) of little use because the radiation could decay to low levels before the material could be used, while those with long half-lives (millions of years) emit radiation very slowly and would do little damage unless inhaled. There is legitimate global commerce in radioactive materials of concern, but also potential for fraudulent purchases and theft during shipment or use, and problems of disposing of sources no longer wanted.[4]

Radiological Dispersal Devices

Alternative Designs. The term "dirty bomb" may have led the media to focus on a device in which powdered radioisotope surrounds chemical explosive. Many terrorist groups would have the skill and materials to make the explosive part of the device; it would be somewhat harder for them to obtain the radioactive material and convert it to powdered form. Terrorists could also scatter radioactive material without an explosive.

Effectiveness. An RDD's effectiveness depends on many factors. (1) Some isotopes do more harm than others, and some elements (including their radioisotopes), such as cesium, bond strongly to concrete and asphalt. (2) Smaller particles disperse more easily and are more readily inhaled, but may be harder to make. (3) Using more material increases physical effects. (4) More explosive would disperse the material more widely. (5) Weather would play a large role. Higher wind speed would disperse the material more widely, and wind direction would determine where it would fall. Thermal currents, more prevalent on a summer's day than a winter's night, would also disperse material. Rain or snow would wash material out of the air but concentrate it in rivers, lakes, and seacoasts. Greater dispersion would increase the number of people affected while reducing the effect on each; less dispersion would inflict more effects but on fewer people.

Several estimates have appeared on radiation levels from dispersal of radioactive material. For example, the Federation of American Scientists calculated that the cesium-137 in a medical gauge, a small amount, detonated in an RDD at the National Gallery of Art in Washington, would cover about 40 city blocks with radiation that would exceed Environmental Protection Agency (EPA) contamination limits (a one in 10,000 chance of getting cancer). This area might, depending on wind direction, include the Capitol, Supreme Court, and Library of Congress. "If decontamination were not possible, these areas would have to be abandoned for decades," by one estimate.[5] Others feel that such scenarios exaggerate the effectiveness of RDDs by assuming that material disperses well and by downplaying the ability to decontaminate affected areas. EPA guidelines magnify RDD effectiveness. Steven Koonin, Provost of California Institute of Technology, stated that 3 curies of an appropriate isotope, a fraction of a gram, dispersed over a square mile "would make the area uninhabitable, according to the maximum dose currently recommended for the general population." However, "the health effects of such contamination would be minimal. For every 100,000 people exposed to that level of radiation, four lifetime cancers would be induced, which would take place on top of the

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[4] Much of the material in this paragraph is from Ferguson et al., *Commercial Radioactive Sources*, p. vi, 3, 12, 13, 43-44.

[5] U.S. Congress. Senate. Committee on Foreign Relations. *Dirty Bombs and Basement Nukes: The Terrorist Nuclear Threat*, hearing, 107th Congress, 2nd Session, 2002, p. 39-40.

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20,000 cancers already expected to arise from other causes."[6] Even such low-level effects are debated; some argue that these effects are extrapolations from higher doses with no conclusive evidence to support their existence.[7]

Terrorists could try to achieve several goals with RDDs in the following sequence. Most depend on public fear of *any* radiation rather than actual levels of radiation. (1) Deaths and injuries. Any prompt casualties would most likely come only from the explosion of a dirty bomb; many experts believe these would be few in numbers.[8] (2) Panic. Small amounts of radioactive material might cause as much panic as larger amounts. (3) Recruitment. The worldwide media coverage of an RDD attack would be a powerful advertisement for a terrorist group claiming responsibility. (4) Asset denial. Public concern over the presence of radioactive material might lead people to abandon a subway system, building, or university for months to years. (5) Economic disruption. If a port or the central area of a city were contaminated with radioactive material, commerce there might be suspended. (6) Long-term casualties. Inhalation of radioactive material or exposure to gamma sources could lead to such casualties, probably in small numbers.

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Prevention and Response

Securing Radioactive Sources. Prior to September 11, 2001, safe handling of sources was the chief concern. They were used worldwide in medical equipment, oil well gauges, etc., with little security. Some were abandoned, becoming "orphan sources." After the attacks, attention shifted to securing them. Various measures seek to control U.S. radioactive materials. The Nuclear Regulatory Commission (NRC) regulates the use and transportation of most radioactive sources for nuclear reactors, for medical, industrial, and academic uses, and related facilities.[9] Many states share in regulation. An NRC-Department of Energy (DOE) working group to increase the security and regulatory oversight of high-risk radioactive sources has proposed verifying the legitimacy of applicants for licenses, preventing insiders from diverting sources, and controlling imports and exports of sources.[10] Several programs provide for the disposal of unwanted radioactive sources, which can be difficult. EPA's Orphan Sources Initiative will establish a national system to retrieve radioactive sources from non-nuclear facilities like

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[6] Senate Foreign Relations Committee, *Dirty Bombs and Basement Nukes*, p. 17.

[7] See U.S. General Accounting Office. *Radiation Standards: Scientific Basis Inconclusive, and EPA and NRC Disagreement Continues.* RCED-00-152 June 30, 2000.

[8] Richard Meserve, former Chairman, Nuclear Regulatory Commission, held that an RDD might cause "deaths on the order of tens of people in most scenarios." Senate Foreign Relations Committee, *Dirty Bombs and Basement Nukes*, p. 8.

[9] U.S. Nuclear Regulatory Commission, "Medical, Industrial, and Academic Uses of Nuclear Materials" [http://www.nrc.gov/materials/medical.html]; and "How We Regulate," [http://www.nrc.gov/what-we-do/regulatory.html#evaluating]. For legislation establishing and governing NRC, see [http://www.nrc.gov/who-we-are/governing-laws.html].

[10] Richard Meserve, Chairman, "Statement Submitted by the United States Nuclear Regulatory Commission to the Subcommittee on Oversight and Investigations, Committee on Energy and Commerce, United States House of Representatives Concerning Nuclear Security,"Mar. 18, 2003.

scrap yards and dispose of them.[11] The Off-Site Source Recovery Project, operated by Los Alamos National Laboratory, gathers sources owned by, or the responsibility of, the Department of Energy from around the United States, transports them to Los Alamos, and stores them there.[12] The National Nuclear Security Administration's (NNSA's) Nuclear Radiological Threat Reduction Task Force is consolidating that and other programs to secure high-risk radioactive material worldwide.[13]

Some international efforts seek to secure sources. This goal is important; according to one expert, over 100 countries in 1999 were "known or thought to lack effective control over radiation sources and radioactive materials."[14] In March 2003, the International Atomic Energy Agency (IAEA) held an International Conference on Security of Radioactive Sources.[15] In June 2002, the G-8 committed itself to "six principles to prevent terrorists or those that harbour them from acquiring or developing" radiological and other WMD.[16] NNSA has identified 35 large radiological waste sites and over 1,000 orphan or surplus radioactive sources in the former Soviet Union, and has initiated a cooperative program with the IAEA and these republics to locate and secure these sites and sources.[17] The IAEA has begun discussions with source manufacturers and suppliers to address alternate sources, possible fraudulent purchases, and source disposal options.

Avoiding the Use of Radioactive Sources. For some uses, radioactive material is the only way to achieve the desired result. For others, alternatives exist, such as x-ray machines or particle accelerators. These machines use electric power to generate radiation, have no radioactive material, and are not radioactive when the power is off.

Detection. RDDs are the least difficult WMD to detect. Chemical or biological agents in airtight containers have no signatures by which they could be detected. RDD-suitable material is more detectable than the highly enriched uranium or plutonium-239 used in nuclear weapons because it is much more radioactive. Hiding radioactive material would require much shielding that could raise suspicions if seen on an x-ray inspection machine, and infrared detectors can detect the heat generated by large radioactive sources despite shielding. Many sensors can detect radioactive material, such as Geiger counters, gamma-ray detectors, and (at short range) pager-size radiation detectors used by Customs and Border Protection (CBP) agents. Portal monitors detect radiation in nearby sources,

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[11] U.S. Environmental Protection Agency. "Orphan Sources Initiative." http://www.epa.gov/radiation/cleanmetals/orphan.htm

[12] For further information on this program, see [http://osrp.lanl.gov].

[13] U.S. Department of Energy. National Nuclear Security Administration. "NNSA Forms New Task [Force] to Address Nuclear and Radiological Threats," press release, November 3, 2003.

[14] Abel Gonzalez, "Strengthening the Safety of Radiation Sources & the Security of Radioactive Materials: Timely Action," *IAEA Bulletin*, 41/3/1999: 9.

[15] See [http://www.iaea.org/worldatom/Press/Focus/RadSources/index.shtml].

[16] G8, "The G8 Global Partnership Against the Spread of Weapons and Materials of Mass Destruction," June 27, 2002, [http://www.g7.utoronto.ca/summit/2002kananaskis/arms.html].

[17] U.S. Department of Energy. Office of Management, Budget and Evaluation/CFO. *FY 2004 Congressional Budget Request: National Nuclear Security Administration*, DOE/ME-0016, vol. 1, February 2003, p. 649-651. [http://www.mbe.doe.gov/budget/04budget/content/defnn/nn.pdf]

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such as vehicles or containers. CBP is installing them nationwide at sea, land, and air ports.[18] NNSA is deploying them in Russia and elsewhere through its Second Line of Defense program, and in other ports through its Mega-Ports program.[19] Detecting RDDs, though, is not simple. Material might be smuggled across unguarded stretches of coasts or borders or obtained within the United States, so a system to detect RDDs inside this nation might be needed to complement border detection efforts. The difficulty of finding RDD material emphasizes the value of eliminating or securing it.

Advance Steps to Minimize Effects of an RDD Attack. As noted earlier, most such effects flow from *fear* of radiation. A large-scale public education program, available for use in the event of attack, could help quell panic.[20] Other steps might include deploying radiation detectors in large cities, and developing and applying coatings to prevent radioactive material from bonding to streets and buildings, though it is not clear that the benefit of coatings would merit the cost.

Response to an Attack. The initial response would likely involve detecting an attack, evacuating areas that might receive radiation or keeping people indoors until respirable material had dispersed, treating people who might be exposed, and sheltering evacuees. The Federal Radiological Emergency Response Plan[21] would come into play. DOE's Nuclear Emergency Support Teams, among others, could assist.[22] Harry Vantine, of Lawrence Livermore National Laboratory, suggests having the prompt ability to predict dose to the population from an RDD attack, and exercising decontamination procedures.[23] A public education program could be implemented promptly. Longer-term responses would include monitoring radiation levels, defining and decontaminating affected areas, and decontaminating or demolishing affected buildings. Promulgating standards that permitted exposure to somewhat higher levels of radiation while having few adverse health effects, as noted above, would greatly reduce the area to be abandoned and the decontamination required. Public acceptance of such standards would be uncertain.

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[18] U.S. Department of Homeland Security. Customs and Border Protection. "Radiation and Portal Monitors Safeguard America from Nuclear Devices and Radiological Materials." c. 2004.

[19] U.S. Department of Energy. Office of Management, Budget, and Administration/CFO. *FY 2005 Congressional Budget Request.* volume 1, National Nuclear Security Administration. DOE/ME-0032, February 2004, p. 447, 454, 455.

[20] For information on coping with RDD attack and other emergencies, see U.S. Federal Emergency Management Agency, *Are You Ready?: A Guide to Citizen Preparedness,* revised September 2002, 101 p. [http://www.fema.gov/areyouready/]; National Council on Radiation Protection and Measurements, "Management of Terrorist Events Involving Radioactive Material," 2001, 232 p., NCRP report 138, [http://www.ncrp.com/ncrprpts.html]; and RAND, *Individual Preparedness and Response to Chemical, Radiological, Nuclear, and Biological Terrorist Attacks,* 2003, 232 p. [http://www.rand.org/publications/MR/MR1731].

[21] See [http://www.au.af.mil/au/awc/awcgate/frerp/frerp.htm].

[22] See Jeffrey Richelson, "Defusing Nuclear Terror," *Bulletin of the Atomic Scientists,* March-April 2002: 39-43; and U.S. Department of Energy. Order DOE 5530.2, "Nuclear Emergency Search Team," Sept. 20, 1991, at [http://www.fas.org/nuke/guide/usa/doctrine/doe/o5530_2.htm].

[23] Senate Foreign Relations Committee, *Dirty Bombs and Basement Nukes,* p. 55.