

# **Ensuring the Security of Radioactive Sources: National and Global Responsibilities**

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## ABOUT THE AUTHOR

Charles D. Ferguson has been the president of the Federation of American Scientists (FAS) since January 1, 2010. Ten years prior to this appointment, he worked for FAS on nuclear proliferation and arms control issues as a senior research analyst and director of the nuclear policy project. At the Council on Foreign Relations (CFR), he served as the project director of the Independent Task Force on US Nuclear Weapons Policy, chaired by William J. Perry and Brent Scowcroft. In addition to his work at CFR where he specialized in arms control, climate change, energy policy, and nuclear and radiological terrorism, he worked until January 2012 as an adjunct professor in the security studies program at Georgetown University.

From 2002 to 2004, Dr. Ferguson had been with the James Martin Center for Nonproliferation Studies (CNS) as its scientist-in-residence. At CNS, he co-authored the book *The Four Faces of Nuclear Terrorism* and was also lead author of the award-winning report “Commercial Radioactive Sources: Surveying the Security Risks,” which was published in January 2003 and won the 2003 Robert S. Landauer Lecture Award from the Health Physics Society. He has also consulted with the Oak Ridge National Laboratory, Sandia National Laboratories, and the National Nuclear Security Administration. From 2000 to 2002, he served as a physical scientist in the Office of the Senior Coordinator for Nuclear Safety at the US Department of State, where he helped develop US government policies on nuclear safety and security issues. His most recent book, *Nuclear Energy: What Everyone Needs to Know*, was published in May 2011 by Oxford University Press.

After graduating with distinction from the United States Naval Academy, he served as an officer on a fleet ballistic missile submarine and studied nuclear engineering at the Naval Nuclear Power School. He received his undergraduate degree in physics from the United States Naval Academy in Annapolis, Maryland, and his M.A. and Ph.D. degrees, also in physics, from Boston University in Massachusetts.

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# Ensuring the Security of Radioactive Sources: National and Global Responsibilities

*Charles D. Ferguson*  
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## INTRODUCTION TO RADIOACTIVITY AND RADIOACTIVE MATERIALS

For most of human existence, people were unaware of the powerful nuclear forces deep inside atoms, although they were exposed to natural background radiation derived from these forces. Not until the end of the 19<sup>th</sup> century did the first “nuclear scientists,” notably Henri Becquerel and Marie and Pierre Curie, discover energetic rays emanating from certain types of atoms due to these forces. For example, Becquerel serendipitously found evidence of this energy source emitted by uranium atoms by examining the exposure of a photographic plate left next to some uranium ore. Coining the term radioactivity to describe these energetic rays, the husband and wife team of the Curies were soon discovering new radioactive elements, in particular, polonium, named after Marie’s native Poland, and radium, named after radioactivity. By painstakingly sifting through hundreds of tons of uranium ore, the Curies isolated grams’ worth of radium and analyzed radium’s radiation.

Because of its relative natural abundance and its powerful radiation, radium became a workhorse radioactive substance for the first half of the 20<sup>th</sup> century. Not until the development of nuclear reactors in the 1950s to make radioactive materials for research and commercial purposes was naturally occurring radium eclipsed by artificially produced radioactive materials. In the early decades of nuclear science, radium seemed like a miraculous material, and some people thought it had tonic properties. Indeed, its radiation can be directed against tumors to fight cancer. Many commercial applications were sought and found. For example, paint laced with radium was applied to watches to make glow-in-the-dark watch dials. But this usage also demonstrated radium’s dark side when numerous young women who had painted on the radium by wetting the tip of the brush with their tongues eventually developed cancers. Having won two Nobel Prizes for her pioneering work, Marie herself could not outwit the harmful effects of decades of exposure to ionizing radiation emitted by radioactive materials. Her notebooks are still contaminated with such materials. The lessons learned from the earliest decades of nuclear science have led to the development of increasingly high standards for the safe and secure use of these materials that have provided benefits to billions of people worldwide.

Before examining the national and international efforts to control and secure radioactive materials, it is necessary to understand the basic principles of the science of ionizing radiation and radioactive materials. The next section presents a risk assessment of the safety and security of these materials. This is followed by a discussion of various pathways for malicious use of commercial radioactive sources. The final section will describe the many efforts underway to reduce the risk of radiological terrorism and makes

recommendations for the inclusion of this issue at the 2012 Seoul Nuclear Security Summit (“Seoul Summit”) and beyond.

## FUNDAMENTALS OF IONIZING RADIATION AND RADIOISOTOPES

Ionizing radiation can knock negatively charged electrons off uncharged atoms, thus creating positively charged atoms, or ions. Radioactive materials can emit various types of ionizing radiation, including alpha particles (which have a double positive charge but are not very penetrating), beta particles (which have either a single negative or positive charge, and are intermediate in their penetrating power), and gamma radiation (which is highly energetic light and is very penetrating).

Ionizing radiation can damage the cells that compose the tissues in the human body, potentially leading to harmful health effects such as radiation sickness or cancer. Alternatively, directing the radiation at tumors can help fight cancer by destroying cancerous cells. To experience near-term health effects, people would have to receive relatively high exposures of ionizing radiation. This could happen through exposure to an unshielded potent radioactive source. Also, malicious use of radioactive sources can involve dispersal of that material through an explosive device or weapon. But because radiological weapons are typically designed to spread radioactive material over wide areas, the dispersed material would pose a far less potent health threat compared to concentrated amounts of radioactivity near a person. However, if people ingest or inhale significant amounts of radioactive material, they might develop serious health effects. People exposed to even tiny amounts of excess radiation have a very small, albeit non-zero, increase in the probability of developing cancer. Nevertheless, because it could take several years to decades for cancer to develop, many people might live in fear of developing cancer after exposure to even small amounts of radiation in the aftermath of a radiological attack. Therefore, the psychological and social consequences of a radiological attack could linger for many years after the incident and dwarf the physical health effects.

In the event of a radiological attack, authorities would need to know the amounts and types of radioactive materials dispersed in order to assess the potential health threat. The type of radioactive material is known as a radioisotope, which is a different nuclear form of a chemical element. Each radioisotope has a unique combination of neutrons and protons in its nucleus, which determines the chemical and nuclear properties (for example, emission of ionizing radiation) of the material. For example, both uranium-235 and uranium-238 have 92 protons in their nuclei because each is a member of chemical element number 92 (uranium), but they differ in having respectively 143 and 148 neutrons.

Relatively few of the few thousand conceivable isotopes that exist naturally or can be man-made are stable, i.e., non-radioactive. The many that are radioactive have decay rates that vary from split seconds (nanoseconds) to billions of years. The rate of radioactive decay is measured by the time it takes for half a radioactive substance to decay, also known as “half-life.” After seven half-lives have elapsed for a radioisotope, less than one percent of the original amount remains. The radioisotopes with short half-lives, of say an hour, would decay relatively rapidly and would not usually pose a security threat, since their levels of radiation would most likely diminish below the danger threshold quickly before they could be used to bring about prolonged exposure. On the other end of the decay scale, radioisotopes with very long half-lives, greater than a few thousand years, would usually not pose a security threat because these materials are emitting radiation at a relatively slow rate. To picture this concept, imagine standing next to

a lump of a particular radioisotope. Over the course of a human lifetime, the very long lived radioisotopes would emit very little of their radiation. In contrast, people could reduce their exposure to the short lived radioisotopes by staying away from these substances and letting relatively rapid radioactive decay reduce the hazardous amounts of the radioisotope.

Because almost all of the thousands of radioisotopes have very short or very long half-lives, most do not pose significant security threats. The radioisotopes that present a security threat have intermediate length half-lives from days to about a thousand years. Sifting through the few thousand imaginable radioisotopes and selecting those with intermediate half-lives, one finds a couple dozen of significant concern. But half-life is only one criterion in determining which can pose security concerns. An additional criterion is how prevalently radioisotopes in this select group are used in commercially available radioactive sources. After applying these selection criteria, the list pares down to about a dozen radioisotopes of potential security concern. Table 1 lists these radioisotopes and their relevant nuclear properties.

Of this group, some are more of a security concern than others. Those that occur in relatively large amounts in a radioactive source would tend to pose a greater threat than smaller amounts. Often in the literature on radiological terrorism, the term “large amount” is used. The actual mass of radioisotope in “large” radioactive sources is usually small as compared to the kilogram-sized quantities of fissile material dealt with in nuclear weapons. To figure out how large an amount of radioisotope one would find in a radioactive source of security concern, look at the column labeled “specific activity” in table 1. Activity quantifies the number of radioactive decays per second in a mass of radioisotope. Specific activity in turn refers to how much activity there is per unit mass, for example, per gram of material. For instance, consider cobalt-60, which has a specific activity of 40,700 GigaBecquerels per gram or equivalently 1,100 Curies per gram. (A Becquerel is the internationally recognized unit of activity, and it equals one decay per second. Giga equals one billion. Thus, one GigaBecquerel equals one billion decays per second. A Curie is the older unit of activity and is still predominantly used in the United States; it equals the amount of activity in one gram of radium, which equals 37 GigaBecquerels.) For example, the amount of radioactivity in one gram of cobalt-60, which is a gamma emitter, is considered hazardous to someone near an unshielded source of this potency after an exposure of a few minutes. For internal exposures of some of the radioisotopes, such as polonium-210, in table 1, microgram amounts can be fatal. The former Russian spy Alexander Litvinenko died from radiation sickness after ingesting micrograms of polonium-210. Thus, gram-sized or even less massive quantities of certain radioisotopes can pose a safety and security threat.

**Table 1: Radioisotopes of Security Concern<sup>1</sup>**

Radioisotope	Half-Life	Specific Activity GBq/g (Ci/g)	High-Energy Alpha Emissions	High-Energy Beta Emissions	High-Energy Gamma Emissions
Americium-241 (Am-241)	433 years	125.8 (3.4)	Yes	No	Low Energy
Californium-252 (Cf-252)	2.7 years	19,832 (536)	Yes	No	Low Energy
Cesium-137 (Cs-137) [Barium-137m (Ba-137m)]	30 years	3,256 [19,980 million]	N/A	Low Energy [Low Energy]	N/A
	[2.6 minutes]	(88 [540 million])			[Yes]
Cobalt-60 (Co-60)	5.3 years	40,700 (1,100)	N/A	Low Energy [Low Energy]	Yes
Iodine-131 (I-131)	8.0 days	4.8 million (130,000)	N/A	Yes	Yes
Iridium-192 (Ir-192)	74 days	>16,650 (>450) std	N/A	Yes	Yes
		>37,000 (>1,000) high			
Polonium-210 (Po-210)	140 days	166,500	Yes	Low Energy	Low Energy
		-4,500			
Plutonium-238 (Pu-238)	88 years	636.4 (17.2)	Yes	No	Low Energy
Plutonium-239 (Pu-239)	24,000 years	2.33 (0.063)	Yes	Low Energy	Low Energy
Radium-226 (Ra-226)	1,600 years	37 (1)	Yes	No	Low Energy
Strontium-90 (Sr-90) [Yttrium-90 (Y-90)]	29 years	5,180 [20.35 million] (140	N/A	Yes	N/A
	[64 hours]	[550,000])		[Yes]	[Low Energy]

## COMMERCIAL RADIOACTIVE SOURCES: SAFETY AND SECURITY RISK ASSESSMENT

The radioactive materials of greatest security concern are commercial radioactive sources that contain relatively large amounts of ionizing radiation. Most of these sources are sealed in protective casings—typically double-encapsulated stainless steel—to prevent accidental exposure to the radioactive material. Thus, to access this material, one would have to break open the seal. One would need some knowledge of radiation safety to perform this operation without inadvertently exposing oneself to lethal doses of radiation from the most powerful sources.

The International Atomic Energy Agency (IAEA) has categorized radioactive sources in terms of potential harm to human health through various scenarios such as improper application of safety procedures or dispersal by explosion, fire, or other mechanisms. Table 2 lists the definitions of each category from the highest health risk (category 1) to lowest risk (category 5) and also mentions examples of types of sources in each category. Experts have reached a consensus that sources in categories 1 and 2 are truly high

risk. Worldwide, there are a few tens of thousands of sources in these categories, but there are far more sources—millions especially in categories 4 and 5—around the globe.

A debate has occurred within the US and other governments, as well as the IAEA, concerning whether this categorization scheme makes sense from the perspective of security threats. For instance, a category 3 source may not cause much harm to human health but could lead to relatively significant economic damage if dispersed in an urban area with valuable property. Alternatively, dispersed lower level sources may not cause much contamination but may stimulate social and psychological effects. Consequently, the debate has centered on how to quantify contamination, social, and psychological effects from sources below category 2.

Social and psychological effects are related to the real and perceived health effects from radiation. Real effects are classified according to the received dose from radioactive material. Health physicists define two dose regimes: high dose and low dose. High doses can cause near term (within minutes to weeks) health effects. These “deterministic” effects are clearly discernible, showing up as nausea, vomiting, and hair loss, for example, at the onset of the high dose regime, i.e., 75 to 100 Rad, or equivalently, in international units, 0.75 to 1.0 Sieverts, of exposure. For even higher doses of 500 or more Rad (5 Sieverts or greater), death can result. (Rad and Sieverts are units of measurement that quantify the biological effects of ionizing radiation and are calculated by taking into account the amount of radiation energy absorbed by living tissue.) But many radiological terrorism scenarios, especially those causing wide dispersal of radioactive material, would likely cause deterministic health effects in few, if any, people.

Many more people would receive low doses of radiation in these scenarios. Low dose exposures, however, would not result in readily discernible deterministic health effects. Instead, over many years to decades, some members of the exposed population may develop cancer. But because potential cancer development is a complicated process involving not only the exposure to a carcinogen such as radiation but also the capabilities of a person’s immune system, health physicists will not be able to determine exactly who in that population will develop cancer. Thus, low dose exposures are inherently probabilistic, like a roll of dice. Still, knowing the level of radiation exposure, experts can predict based on conservative modeling the fraction of people who would likely develop cancer. This modeling assumes that even very low amounts of radiation result in a non-zero probability of developing cancer. Some health physicists disagree about this modeling and instead believe evidence points to a threshold level of exposure below which people would not develop cancer. The paucity of reliable data in the low dose regime has blocked resolution of this debate.

Concerning radioactive source categorization, experts also disagree about whether to include the probabilistic (what the literature calls, *stochastic*) health effects from the low radiation levels someone might receive from categories 4 and 5 sources. Category 3 sources, as shown in table 2, can lead to even higher levels of radiation exposure but would typically be expected to result in relatively low levels if dispersed in a radiological weapon. The IAEA categorization document excludes stochastic effects from consideration in the categorization criteria because “the deterministic effects resulting from an accident or malicious act are likely to overshadow any increased stochastic risk in the short term.”<sup>2</sup> Although stochastic radiation doses may cause cancer in only a relatively small fraction of the exposed population, worries about stochastic effects could add to the psychological burden as people are witnessing, for example, in the aftermath of the radioactive contamination from the accident at the Fukushima Daiichi Nuclear Power Plant.

Another issue in the debate over source categorization is how to factor in the ease of access to and transport of various sources. Devices containing sources with relatively high amounts of radioactivity tend to weigh much more than devices with lower level sources. For example, a research irradiator, which is a category 1 source, can weigh several hundred kilograms, including all of the lead shielding and metal casing of this device. In contrast, a brachytherapy device, which is a category 3 source, designed to be inserted in the body (for example, to treat prostate cancer), weighs much less than a kilogram and is only millimeters in length. Both types of sources can be found in hospital settings. Assuming terrorists could access a hospital that has these sources, they would have a far easier time carrying brachytherapy sources. If terrorists wanted the larger amount of radioactivity resident in the irradiator, they could try to cut into the device to remove the radioactive material. To be successful, they would need to know about the specific design of the device, possess the proper tools to break into the device, and need shielding to safely handle the radioactive material once they have removed it from the device. Even suicidal terrorists could not simply ignore the risk of radiation exposure as they would likely receive a deterministic and perhaps lethal dose of radiation if they did not shield a removed category 1 source within a few minutes. In sum, category 3 sources with relatively low levels of radioactivity might, under certain circumstances, pose greater security risks than higher activity category 1 or 2 sources.

Another contentious aspect of the debate is how to factor in the security risks of lower level sources that would not cause any appreciable, immediate threat to human health, but could still cause significant contamination. For example, a single category 3 source would likely not contain sufficient radioactivity to cause immediate health effects in a scenario in which the source's radioactive material were dispersed by a radiological weapon. Nonetheless, depending on where the material was dispersed, the contamination could result in significant property damage. It is also important to recognize that the IAEA's source categorization excludes "socio-economic consequences resulting from radiological accidents or malicious acts [because] the methodology to quantify and compare these effects, especially on an international basis, is not yet fully developed."<sup>3</sup> Some independent security experts have recommended considering category 3 sources as high risk, especially when several of these sources are aggregated.<sup>4</sup> The IAEA's source categorization document also draws attention to the aggregation of lower level sources resulting in a cumulative radioactivity amount that would be equivalent to a higher category source.<sup>5</sup> The IAEA thus advises that regulatory authorities may want to track closely the whereabouts of category 3 sources by including them in national registries of sources.

Table 3 lists the most prevalently used sources in categories 1, 2, and 3, along with the typical amounts of radioactivity in each type of source. In addition to radioactivity, the chemical properties of a source can either increase or decrease the security risks. In particular, the chemical form strongly affects the ease or difficulty by which the substance can be dispersed. Cesium chloride tops the priority list of high-risk, easily dispersible radioactive sources because it is a talcum powder-like substance; thus, even just blowing on it could spread it.<sup>6</sup> In contrast, because cobalt-60 is in the form of metal pins or rods, it is much harder to disperse. Iridium-192 also typically exists in solid metallic form. In general, chemicals in the form of talcum or salt-like substances can be more easily dispersed than chemicals that are solid or more tightly bound together.

Only a relatively small number of major manufacturers make the majority of radioisotopes used in commercial radioactive sources.<sup>7</sup> Governments tend to own the reactors that are used to produce these radioisotopes. In particular, major radioisotope production occurs in reactors located in Argentina, Belgium, Canada, France, the Netherlands, Russia, South Africa, and the United States. Several other countries are using research reactors to produce radioisotopes for medical and other commercial purposes,

including Australia, Brazil, China, Germany, Iran, and South Korea, to name a few notable producers. As an illustration of South Korea’s growing capacities in this field, in 2009, it hosted an international training conference on radioisotope production.<sup>8</sup> Radioactive source manufacturers, including those in Belgium, Canada, Russia, South Africa, and the United States, to name the countries with the largest corporations, then place radioisotopes in sealed sources, which are put in devices, such as irradiators, radiography cameras, and teletherapy machines. These corporations then sell the devices to thousands of users throughout the globe. Every country uses radioactive sources. Thus, ensuring the security of these materials is a responsibility for every nation and a shared global endeavor because sources in one country can be stolen and misused in another country.

**Table 2: Categorization of Radioactive Sources<sup>9</sup>**

Categories of Radioactive Sources	Definition and Types of Sources
Category 1: “Extremely dangerous to the person”	These sources “if not safely managed or securely protected would be likely to cause permanent injury to a person who handled [them], or were otherwise in contact with [them] for more than a few minutes. It would probably be fatal to be close to this amount of unshielded material for a period of a few minutes to an hour.” For dispersal scenarios, there “would be little or no immediate health effects to persons beyond a few hundred meters away, [and] ... for large sources the area to be cleaned up could be a square kilometer or more.” This category includes radioisotope thermoelectric generators, research and blood irradiators, and radiation teletherapy sources.
Category 2: “Very dangerous to the person”	These sources “if not safely managed or securely protected could cause permanent injury to a person who handled [them], or were otherwise in contact with [them], for a short time (minutes to hours). It could possibly be fatal to be close to this amount of unshielded radioactive material for a period of hours to days.” For dispersal scenarios, there “would be little or no immediate health effects to persons beyond a hundred meters or so away, [and] ... the area to be cleaned up would probably not exceed a square kilometer.” This category includes industrial radiography cameras, and high-dose-rate and medium-dose-rate brachytherapy sources.
Category 3: “Dangerous to the person”	These sources “if not safely managed or securely protected could cause permanent injury to a person who handled [them], or were otherwise in contact with [them], for some hours. It could possibly be fatal to be close to this amount of unshielded radioactive material for a period of days to weeks.” For dispersal scenarios, there “would be little or no immediate health effects to persons beyond a few meters, [and] ... the area to be cleaned up would probably not exceed a small fraction of a square kilometer.” This category includes oil well logging sources and fixed industrial gauges using high activity sources and includes level gauges, dredger gauges, conveyor gauges, and spinning pipe gauges.
Category 4: “Unlikely to be dangerous to the person,” and Category 5: “Most unlikely to be dangerous to the person”	The sources in these categories contain relatively low activity materials and thus are generally not considered dangerous in the context of most radiological weapons unless a large enough aggregate amount of these sources were collected and used. Examples of sources in these categories are smoke detectors and medical diagnostic sources.

**Table 3: High-Risk Radioactive Sources<sup>10</sup>**

Type of Source or Application	Radioisotope	Typical Radioactivity Level GBq (Ci)	Source Categorization
Sterilization and food irradiation	Cobalt-60	148 million	1
		(Up to 4 million)	
	Cesium-137	111 million	
		(Up to 3 million)	
Radioisotope thermoelectric generator (RTG)	Strontium-90	740,000	1
		-20,000	
	Plutonium-238	10,360	
		-280	
Research and blood irradiators	Cobalt-60	88,800-925,000	1
		(2,400-25,000)	
	Cesium-137	259,000-555,000	
		(7,000-15,000)	
Single-beam teletherapy	Cobalt-60	148,000	1
		-4,000	
	Cesium-137	18,500	
		-500	
Multi-beam teletherapy (gamma knife, e.g.)	Cobalt-60	259,000	1
		-7,000	
Industrial radiography	Cobalt-60	2,220 (60)	2
	Iridium-192	3,700 (100)	
High- and medium-dose brachytherapy	Cobalt-60	370 (10)	2
	Cesium-137	111 (3)	
	Iridium-192	222 (6)	
Well logging	Cesium-137	0.74-74 (0.02-2)	3
	Americium-241/Beryllium	0.74-74 (0.02-2)	
	Californium-252	37 (1)	
	(rare use)		
Level and conveyor gauges	Cobalt-60	0.74-74 (0.02-2)	3
	Cesium-137	0.74-74 (0.02-2)	

## THREATS OF MALICIOUS USE OF RADIOACTIVE SOURCES

Terrorists might choose to use a radiological weapon for one or more purposes: causing harm to human health through exposure to ionizing radiation; provoking psychological effects through stimulation of people’s fears of radiation, as well as disrupting people’s lives and livelihoods; and causing significant economic damage through radioactive contamination of valuable property.

A radiological weapon is not a nuclear weapon, and the effects of the two differ tremendously. For example, a radiological weapon cannot produce a nuclear chain reaction and will not, consequently, result in a massive explosion. The one characteristic common to nuclear and radiological weapons is that both employ radioactive material. A nuclear explosion through fission would produce massive amounts of radioactive material, whereas a radiological weapon cannot produce additional radioactive material than the amount that was originally contained in the weapon. Many experts therefore do not consider a radiological weapon to be a weapon of mass destruction (WMD); rather, they refer to radiological weapons as a different type of WMD: a weapon of mass *disruption*.<sup>11</sup> Massive disruption can result from the economic, social, and psychological effects of a radiological attack.

The radioactive material in a radiological weapon can come from many sources. Nuclear power plants, research reactor facilities, hospitals, blood banks, universities, food irradiation centers, oil well sites, and shipbuilding and construction sites are some of the major places where radioactive materials are used and stored. Some are more vulnerable than others to terrorists obtaining radioactive material.

Nuclear power plants would probably have the most rigorous security and would have materials that are too radioactive to handle without thick shielding and too heavy to carry without special equipment. At these plants, spent nuclear fuel is highly radioactive and could give a lethal radiation dose in a few minutes without adequate shielding. Moreover, a spent nuclear fuel assembly at a commercial plant typically weighs many tons.

Spent fuel from research reactors, on the other hand, may not contain nearly as much radioactivity as at commercial power plants because many research reactors operate at power levels much lower than at their commercial counterparts. Also, a spent fuel assembly at a research reactor can weigh much less than one at a power plant and thus might be more susceptible to transport by thieves. Of course, a terrorist group would have to surmount the barrier of finding out where the spent fuel is located within a facility. Reconnaissance and insider assistance could help provide this information.

At any location where radioactive materials are used, terrorists would have to determine how to gain access, identify where the materials are situated, and figure out how to remove them. If removal proves too much of a problem, the terrorists could try to blow up the material in place. Such a scenario may or may not achieve their intended objectives unless the location itself is considered to be of high enough tactical value to elicit the desired response from the terrorists' intended audience.

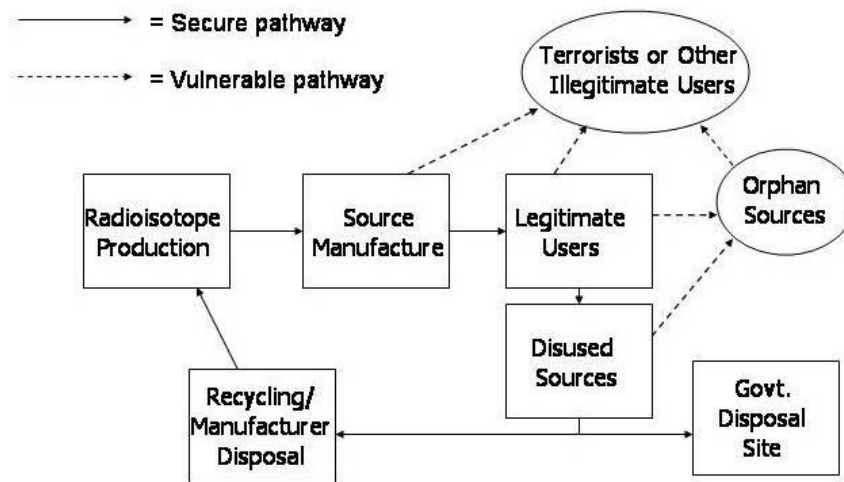
Certain locations where radioactive materials are used or stored appear more accessible than others relative especially to highly secure nuclear power plants. For instance, hospitals and universities are designed to be open to the public. Thus, terrorist reconnaissance of these locations may not attract the attention of authorities. But without specific information about where radioactive materials are located, the terrorists may not identify these locations without additional assistance from insiders or from external sources of information such as Websites about the facilities. Thinking through potentially promising pathways for terrorists to try to acquire radioactive materials, security experts have identified—in addition to insider assistance and theft from facilities—alternative acquisition routes, including deliberate transfer by a government, unauthorized transfer by a government official or a facility custodian, looting during coups or other times of political turmoil, licensing fraud, organized crime, exploiting weaknesses in transportation links, sellers of illicitly trafficked radioactive material, and finding orphan radioactive sources (which have been lost, stolen, or have fallen outside of regulatory control).<sup>12</sup>

Although governments are not known to have deliberately transferred radioactive materials to terrorists,

some might conceivably attempt this. All states possess radioactive sources, and many governments own research reactors that can produce sources that could be useful in radiological weapons. (See the blocks labeled radioisotope production and source manufacture in figure 1.) However, this threat is unlikely to occur because government leaders would fear retribution if the country that was the victim of the attack could trace the radioactive materials to its origin. While nuclear forensics and attribution pose considerable technical challenges, the United States has been working with partner governments and the IAEA in developing and refining these methods. Thus, the transferring government would have to factor into its risk calculations the increasingly credible forensics capability available to many other governments.

Terrorists could try to recruit sympathetic government officials or custodians of facilities containing radioactive sources for unauthorized transfers. A terrorist group would face daunting challenges in exploiting this pathway, however. Possible exploitation techniques include extortion, other types of coercion, or perhaps cooption by winning officials or custodians over to the terrorists' cause. However, none of these methods is easy; terrorists would have to devote sufficient time and resources to open up this pathway and would face the risk of discovery by authorities.

**Figure 1: Radioactive Source Lifecycle**



National or local political turmoil such as the overthrow of a government could create opportunities for looting facilities containing radioactive sources. For example, looting broke out immediately after US-led coalition forces toppled Saddam Hussein from power in Iraq in April 2003. Looters broke into the main Iraqi nuclear site at Tuwaitha, where they accessed barrels that contained uranium yellowcake. Fortunately, that material is weakly radioactive and a very poor choice for use in radiological weapons. Nevertheless, if people ingest significant amounts of uranium, they could suffer from toxic heavy metal health effects. More worrisome, the Tuwaitha site had more powerful radioactive sources than yellowcake. A subsequent IAEA investigation accounted for almost all of the uranium containers, but the status of some of the radioactive sources could not be determined. About a year later, in mid-2004, the US Department of Energy helped secure many Iraqi high-risk radioactive sources; however, terrorists or other malicious people could have accessed some of these sources in the interim if they had known about vulnerabilities at Tuwaitha and other Iraqi facilities.

Instead of stealing sources from facilities or availing themselves of corrupt officials or insiders, terrorists might try to pose as legitimate buyers of sources. This is depicted by the dashed lines in figure 1 leading from source manufacturers and legitimate users to illegitimate users. Terrorists could try, for instance, to file for licenses issued by nuclear regulatory authorities that entitle the holder to own potent radioactive sources. A related option is to create a fraudulent license. For example, while not a terrorist, Stuart von Adelman, who occasionally had exhibited deranged behavior, did just that in the 1990s on more than one occasion. Once he posed as a university physics professor and fraudulently obtained access to radioactive materials. Nonetheless, despite some episodes of irrational behavior, he did serve as a radiation safety officer at two universities and also as a licensing reviewer in a state radiation control program. Although he was never connected to terrorist activity, an assistant US District Attorney stated that the radioactive material Adelman had obtained in Canada may have been used in a scam to earn money from terrorists. In 1996, he was arrested in the United States, pleaded guilty to charges of fraudulent acquisition of radioactive material and was sentenced to five years in prison.<sup>13</sup> In 2006, the US Government Accountability Office showed that its researchers could use fake licenses to acquire radioactive materials.<sup>14</sup> Similarly, illicit buyers could misrepresent themselves on the Internet to try to purchase radioactive sources online. Regulating Internet commerce to guard against illicit radioactive material sales poses challenges.

Terrorists might also try to acquire radioactive materials through links to organized crime. For example, in 2002, a criminal gang stole five radioactive sources in Ecuador and held them for ransom. After paying the fee, the company that had owned the sources only received three of them back. According to the *Washington Post*, this “was the first known case of successful blackmail involving radiological material, and US and UN experts fear the pattern could be repeated.”<sup>15</sup>

Terrorists could link up with buyers of illicitly trafficked radioactive material. The IAEA’s illicit trafficking database has shown many cases of opportunistic thieves trying to pawn off radioactive materials, some involving relatively potent radioactive sources containing cobalt-60 and cesium-137, for instance.<sup>16</sup> The database shows a dramatic increase in the number of cases of reported illicit trafficking in the 2000s as compared to the 1990s, whereas the number of cases of trafficking of highly enriched uranium and plutonium, fissile material useful for nuclear weapons, actually stayed relatively constant between these two time periods. However, this database should be treated with caution because countries are not required to report all incidents; the traffickers who are caught may not have been competent enough to find buyers (many of the traffickers were caught in sting operations); and it is uncertain whether there is a significantly large demand for these materials (unlike the issue of illicit drug trafficking). While analysis of the data does not indicate a convergence between terrorism and illicit radioactive materials trafficking,<sup>17</sup> such a convergence cannot be ruled out in the future.

Another database that includes all open source reports as well as government confirmed incidents on illicit trafficking of radioactive and nuclear materials is the Database on Nuclear Smuggling, Theft, and Orphan Radiation Sources (DSTO), which was created at Stanford University in 1999 and has been maintained at the University of Salzburg since 2004. The DSTO data from 1991 to 2010 show: “1674 incidents of thefts, illegal movement, and border detections of radioactive materials, 736 cases of the so called orphan sources, which have been lost, accidentally found or misrouted on the way to the recipient, and 35 malevolent acts, such as intentional irradiation of persons and contamination of their residencies and belongings.”<sup>18</sup>

Finally, terrorists might try to find radioactive sources that have been abandoned, also known as “orphaned” sources. They might use radiation detectors such as Geiger counters to find these sources

given some knowledge about where to look. For instance, within the former Soviet Union, there are estimated to be hundreds of orphan sources. The IAEA, the Russian Federation, other former Soviet republics, and the United States have been working together since the 9/11 terrorist attacks to track down these sources. While many have been found, many more are believed to still be orphaned because of the Soviet legacy production of large numbers of powerful radioactive sources.

## TYPES OF RADIOLOGICAL WEAPONS

Radiological weapons can take a variety of forms, from crude explosive devices to sophisticated dispersal mechanisms. Unfortunately, the news media have latched onto the term “dirty bomb” to describe all types of radiological weapons, portraying a limited view of these weapons. The popular image of a dirty bomb usually consists of conventional explosives, say TNT, strapped to some type of radioactive material. When the explosives are ignited, the resulting blast disperses the radioactive material. But this dispersal mechanism might not effectively spread out radioactive material in ways that can do serious harm to health or result in significant radioactive contamination that is hard to clean up. Based on studies done at Sandia National Laboratories by Fred Harper and colleagues, most dirty bombs would not produce significant amounts of aerosolized radioactive material and thus would not pose significant health risks for inhalation.<sup>19</sup>

To optimize production of aerosolized material, terrorists would have to be skilled in conventional explosives and know how to choose the correct types and amounts of explosives depending on the chemical composition and amount of radioactive material present. They would also need to have knowledge of the chemistry and physical form of the radioactive source. In particular, they would need to know whether the source is a solid, liquid, or powder. To move beyond a simple dirty bomb, a terrorist group would have to assemble experts with the correct skill sets and do their homework on the radioactive material they have accessed or are attempting to access.

If a terrorist group bent on using a radiological weapon had these skills, a larger number of radiological weapons would be available to them. Radiological dispersal device (RDD) is the term in the literature, outside of press stories, that is used to describe many types of radiological weapons.<sup>20</sup> An RDD could use dissolved radioactive material in a liquid-like solution. In this chemical form, sprayers would disperse the solution. Similarly, radioactive materials already in a powdered form would be dispersed through such mechanisms. For example, conceivably, cruise missiles or unmanned aerial vehicles could disperse these solutions or powders by flying low over urban areas or other high value targets.<sup>21</sup> But making the most hazardous-sized aerosolized particles, around one to a few microns in diameter, is far from easy to do.<sup>22</sup> Meteorological conditions can also significantly affect the ability to disperse hazardous clouds of radioactive materials with these methods.

Drawing upon some of these earlier studies about sprayers, James Acton, Brooke Rogers, and Peter Zimmerman in 2007 drew attention to “inhalation, ingestion, and immersion (I<sup>3</sup>) attacks.”<sup>23</sup> An inhalation attack would try to make victims breathe in and retain much of the radioactive material in their lungs; an ingestion attack would involve swallowing radioactive material; and an immersion attack would soak victims with the material in some type of solution or colloidal suspension of the material in a liquid. Acton *et al* cautioned that radiological security experts have largely overlooked the seriousness of these

types of radiological attacks. Instead, much more attention has been focused on dirty bombs and other explosive means of dispersing radioactive materials.

They discussed two main reasons to be concerned about I<sup>3</sup> attacks. First, inhalation, ingestion, and immersion attacks would increase internal health hazards because these methods are designed to bring radioactive materials into the body. As the murder in November 2006 of former Russian spy Alexander Litvinenko with only micrograms of polonium-210 illustrated, “once inside the body, even a minute quantity of a radioactive material can be deadly.”<sup>24</sup> Alpha-emitting materials such as polonium-210 are well suited for I<sup>3</sup> attacks because only a few hundredths of a Curie of internal alpha radiation exposure can cause serious health effects (when inhaled or ingested). Second, while the most effective I<sup>3</sup> attacks require significant technical skills, relatively simpler versions of these attacks are likely within the skill set of reasonably technically competent terrorists.

Examining other means of dispersal, terrorists might consider using incendiary devices to disperse radioactive materials. A radiological incendiary device (RID) would complicate firefighters’ efforts at fighting a fire and rescuing people from a burning building while contending with radioactive contamination.<sup>25</sup> Even if the health risk from the radioactivity is not high, people who are experiencing the fire already have a tendency toward panic and might feel even more panicky if they knew that there was radioactive contamination as well.

Radiological weapons need not disperse radioactive materials to be useful instruments of terrorism. A radiation emission device (RED), for example, emits ionizing radiation from a stationary radioactive source. Thus, people closest to the source would receive the largest radiation dose. The intensity of this point source radiation is inversely proportional to the distance squared. For example, moving twice the distance away from the source would reduce the radioactivity intensity by a factor of four. Terrorists contemplating this simple type of radiological weapon would likely choose crowded locations such as urban train stations, concert halls, or sports arenas.

Terrorists’ communication strategies would be critical in all radiological attack scenarios but perhaps even more so in an RID because of the fear associated with fire. For instance, the perpetrating group might contact the news media just before or soon after the attack started to increase the likelihood of stimulating people’s anxieties. Alternatively, the group might decide to keep quiet and allow the authorities to find the radioactivity, leaving governments and citizens wondering and worrying about a possible next attack.

## **REDUCING THE RISK OF RADIOLOGICAL TERRORISM: NATIONAL AND INTERNATIONAL EFFORTS**

While the 2010 Nuclear Security Summit in Washington, DC, was unprecedented in the high-level global attention devoted to securing fissile materials from potential terrorists or other non-state actors, several political leaders felt that a major gap on the summit’s agenda was the lack of attention to securing radiological materials. (The work plan published by the White House did mention as the final and eighth point on the subject of peaceful uses of nuclear technologies that “participating States will consider how to best address the security of radioactive sources, as well as consider further steps as appropriate.”<sup>26</sup>) In press interviews during the summit, Pakistani Prime Minister Syed Yusuf Raza Gilani emphasized that “the threat of dirty bombs is more real and it has global dimensions.” German Chancellor Angela

Merkel also viewed radiological weapons as a greater terrorist threat than nuclear weapons.<sup>27</sup> However, for the Washington Summit, US government officials wanted to keep the agenda tightly focused on securing fissile materials because of the greater devastating consequences of nuclear explosions and because President Obama had pledged during a speech in Prague in 2009 to lead the world in securing all vulnerable nuclear materials within four years.<sup>28</sup>

In the November 2010 preparatory meeting in Buenos Aires for the 2012 Seoul Summit, several representatives of various governments expressed interest in including the security of radiological materials on the summit's agenda.<sup>29</sup> Notably, Ambassador Cho Hyun of the Republic of Korea, then the ROK's Sherpa for the Summit, was instrumental in expanding the agenda and specifically mentioned this issue at the December 2010 nuclear security and nonproliferation conference on South Korea's Jeju Island.<sup>30</sup> Security experts from the nongovernmental community also helped push forward the inclusion of radiological materials in articles and conference talks throughout 2010 and 2011.<sup>31</sup> However, there is still concern from some world leaders that the inclusion of this issue will distract focus from securing nuclear materials.

### **Radiological Security Risk Assessment**

Given the various pathways to acquiring radioactive sources and the various types of weapons, it might appear puzzling that no radiological attacks have occurred. While most terrorist groups appear uninterested in radiological strikes, there has been enough interest shown by some that one cannot rule out an attack in the future. For instance, there have been instances in the past twenty years in which Chechen rebels and members of al Qaeda and affiliated terrorists have shown interest in acquiring radioactive sources. In 1995, for example, Chechen rebels directed a Moscow television crew to Ismailovsky Park where they had placed a cesium-137 source, but they did not detonate the material. One can speculate why not, although given the paucity of data, a clear explanation is lacking.

Some hypotheses, however, try to explain the non-occurrence of radiological attacks as of early 2012 are: 1) the few groups like al Qaeda and the Chechen rebels that appear relatively highly motivated have been decimated or may perceive that the costs of crossing the threshold to a radiological attack outweigh the benefits; 2) even if that is not true, these groups are having trouble gaining access to potent radioactive sources that would create the level of damage they seek; 3) members of these groups are concerned that they might harm themselves if they mishandle highly radioactive materials (even suicidal terrorists have to survive long enough to deliver the weapon); 4) the groups that would be motivated tend to be risk averse and thus reluctant to try unproven methods; 5) similarly, they would not want to displease the higher religious or other powers they serve and consequently avoid risky operations; 6) the efforts to prevent a radiological attack by securing sources and deploying radiation detection equipment are having a deterrent effect; and 7) despite conventional wisdom that terrorists would benefit strategically from these attacks, they may not have this perception.<sup>32</sup> Jonathan Medalia, a nuclear policy expert at the Congressional Research Service, also observes that possible reasons for the absence of radiological attacks "may include difficulties in handling radioactive material, lack of sufficient expertise to fabricate material into an effective weapon, a shift to smaller but simpler attacks using standard weapons, and improved security. Of course, such factors still cannot guarantee that no attack will occur."<sup>33</sup>

While the world has been fortunate to date, luck could run out. Further good news is that the financial resources required to secure radioactive sources and continue to reduce the risk of radiological attacks are

relatively small. For instance, tens of millions of dollars annually during the past decade has been used successfully to secure tens of thousands of sources around the globe.

### **Radiological Security Governance Structure**

While states do not have an international legal requirement to meet certain standards concerning securing radioactive sources, several international efforts have created a web of what is considered responsible practices. The strands of this web include the IAEA Code of Conduct on the Safety and Security of Radioactive Sources, UN Security Council Resolution 1540, and the G-8's Global Partnership.

Although not a binding convention, the Code of Conduct on the Safety and Security of Radioactive Sources and its companion Guidance on Import and Export of Radioactive Sources provide states with best practice advice. Major recommendations of the code include: 1) require possessors of sources to be authorized and licensed by competent regulatory authorities; 2) conduct announced and unannounced inspections of licensees' facilities; 3) ensure adequate security throughout sources' lifecycle from production of radioisotopes in reactors to disposal of disused sources in government licensed facilities or recycled by manufacturers; 4) require inventory controls by licensees in order to reduce the likelihood of orphan sources; 5) create confidential, national registries of high risk sources to track them during their use by licensees; and 6) implement improved export controls that ensure that only authorized users receive the transferred sources. The majority of the world's states have pledged to uphold this code.

Unlike the code, UN Security Council Resolution 1540 is legally binding on all states because it was passed (unanimously) in April 2004 by the Security Council under Chapter VII of the UN Charter. This resolution calls on all states to ensure that they have proper and adequate national legislation and regulatory controls. While the focus of this resolution is on stopping non-state actors from acquiring the means to make nuclear, chemical, and biological weapons, the resolution is relevant to radioactive sources in that states can apply any overhauls in domestic legislation to similar changes needed to improve the security of sources. Moreover, the resolution requires states to improve means of detecting illicit trafficking, including more effective law enforcement cooperation among states and better means of interdicting materials at border crossings.

Similar to UNSCR 1540, the G-8 Global Partnership has sought to focus its efforts on preventing the use and acquisition of weapons of mass destruction by non-state actors. The Global Partnership initially concentrated its effort on the states of the former Soviet Union but has since expanded outside of this geographic region. The G-8 has also broadened its scope of action to encourage better practices to secure radioactive sources. In particular at the 2003 Summit in Evian, France, G-8 leaders endorsed the Code of Conduct on the Safety and Security of Radioactive Sources, called on states to support and advance the work of the IAEA's programs, "considering the provision of additional resources as necessary to the Nuclear Security Fund," and urged continued global awareness about the need to improve security of sources. Subsequent G-8 summits have made similar statements.

Arguably the best news is that the elements for strategic and operational plans for reducing the risk of radiological terrorism have been identified and are generally being applied, as indicated by the principles in the Code of Conduct and the work of the IAEA's Office of Nuclear Security. The issue, however, before world leaders as they prepare for the Seoul Summit and as they and their governments look beyond that meeting, is the commitment to devote adequate resources toward a systematic and sustainable action plan.

### **Work Plan Recommendations: A Defense-in-Depth Approach**

A defense-in-depth or layered security approach offers a mechanism to build up an increasingly strong system of radiological risk reduction. While each layer is imperfect and does not provide 100 percent protection, the combined effect is an overall protection that can be much greater than each individual layer. A related concept is to make sure that even if a terrorist can defeat all security systems and can carry out a radiological attack, measures such as emergency response and decontamination will mitigate the consequences and thus reduce the risk.

Since risk is likelihood (or probability) multiplied by consequences, an effective defense-in-depth plan will reduce both likelihood and consequences. Reducing likelihood involves improving security of radioactive sources, decreasing use of certain types of very potent or dispersible materials, enhancing regulatory controls, improving export controls, increasing government cooperation in intelligence sharing about threats, deploying radiation detectors, rounding up orphan sources, and developing improved disposal and recycling pathways for sources. Reducing consequences involves developing and deploying better decontamination technologies, improving the training of emergency first responders, and increasing the capacity for effective international response to radiological incidents.

#### *Improving Security of Radioactive Sources*

The most important action in reducing the risk of radiological terrorism is to increase the security of radioactive sources. It is equally important to recognize that simply locking up sources is not a cure all. These sources are designed for commercial use and many are used daily in hospitals, universities, and other open access settings where a “gates, guards, and guns methodology” or mentality is not feasible. An alternative is to build security features into the design of devices that contain sources. Another measure would be to put in place signaling mechanisms in these devices to alert authorities if and when a theft has occurred. Still another best practice is to ensure that there are proper background checks on personnel authorized to access potent sources.

The US government, in particular, has worked with dozens of countries to install security enhancements in facilities and on devices that contain potent radioactive sources. As of September 2011, the US-led Global Threat Reduction Initiative (GTRI) has completed security enhancements at 1,082 high-priority nuclear and radiological buildings both domestically and overseas. This includes 261 US facilities containing high-risk radioactive sources and 790 facilities in other countries. The bad news is that many more buildings need security upgrades with an estimated 2,700 in the United States and 5,800 in the 80 plus countries outside of the United States under the scope of the GTRI program.

The IAEA’s Office of Nuclear Security in the past two decades has provided assistance, equipment, and advisory services to numerous Member States. It is important to point out that this office assists Member States with security of both nuclear materials and radioactive sources. Often, the same training sessions can cover both types of substances, but because of the more widespread use of radioactive sources in medicine, industry, and scientific research, there will be different security considerations that take into account the wider variety of applications as compared to nuclear materials. The overarching approach of the IAEA’s Office of Nuclear Security is “to strengthen [States’] capacity to prevent, detect, and respond” to nuclear and radiological terrorism.<sup>34</sup>

For the Seoul Summit and work continuing after the summit, national leaders should devote resources to these IAEA programs and adopt the best security practices being implemented by the IAEA and GTRI.

Moreover, states should share technologies that would substantially delay stealing of sources from inside equipment. Such delays would allow law enforcement more time to respond. Regarding methods to assist response forces, South Korea has developed tracking technologies for radioactive sources using Global Positioning System's signals and reportedly intends to share this technology with other countries.<sup>35</sup>

#### *Decreasing Use of Certain Types of Very Potent or Dispersible Radioactive Materials*

Radioactive sources will continue to be used worldwide because of the benefits these sources provide. However, replacement technologies are available for some types of powerful sources. For example, particle accelerator technologies have been used to replace many teletherapy sources, which are used to destroy cancerous cells. The accelerators only produce radiation when there is electrical power; thus, they do not pose a radiological dispersal threat unlike radioactive sources, which are always "on" due to their continual radioactive decay. Other technologies could replace some blood or research irradiator sources or oil well logging sources. But development of replacement technologies will not occur unless there is commercial viability. Companies that develop these technologies will have to compete with others that manufacture devices containing radioactive sources.

A related issue is the development of less dispersible forms of highly dispersible sources. The exemplar of this concern is cesium chloride because of its talcum powder form. While there has been some research into making radioactive cesium-137 in a ceramic or other form that cannot readily be dispersed, these efforts have run into the technical challenge of making sure that the density of cesium in these is similar to that in the chloride form. Moreover, manufacturers can be reluctant to retool their manufacturing processes if the conversion is too expensive and if it could put them at a competitive disadvantage.

For the Seoul Summit and beyond, national leaders can consider public-private partnerships that would foster research, development, and demonstration of commercial viability of replacement technologies for many of the riskiest sources. In February 2008, the US National Research Council, in a report on replacement of high-risk sources, discussed several options, including: stop the licensing of cesium chloride irradiators; discontinue the import and export of such devices; create government incentives for owners to decommission and dispose of the current sources; buy back by the government of no longer needed irradiators, basing the price offered on the age of each device; provide for government financial incentives to lower the cost of developing and commercializing replacement technologies; and create certification incentives for such technologies to encourage greater use.<sup>36</sup>

#### *Enhancing Regulatory Controls*

Dozens of nations have weak regulatory controls on radioactive sources. In the 1990s, the IAEA started the Model Project to assess states' regulatory agencies and offer advice and assistance for improving regulatory controls. Building on the work of the Model Project, the IAEA's Office of Nuclear Security's International Nuclear Security Advisory Service (INSServ) currently offers comprehensive assessments that include measures against illicit trafficking and control of radioactive sources. Also, the IAEA's Radiation Safety and Security Infrastructure Appraisal (RaSSIA) assesses "the effectiveness of national regulatory infrastructures for radiation safety and security of radioactive sources against established international standards." RaSSIA personnel work with national authorities to form an action plan "designed to bring the regulatory infrastructure up to international standards."

National leaders at the Seoul Summit and in continuing efforts would be well advised to support the IAEA's programs in assisting regulatory agencies. Specially, adequate and dedicated funding to the

IAEA's Office of Nuclear Security for this type of work will help ensure that this office can plan for sustainable assistance over multiple years. In contrast, this office has mostly had to rely on voluntary contributions that have varied year by year.

### *Improving Export Controls*

At the 2004 G-8 Summit, leaders committed to enhancing export controls on radioactive sources. Since then, significant changes in export control laws and regulations have occurred. The focus initially on the G-8 was very appropriate because most of the major manufacturers of radioactive sources are headquartered in G-8 nations. But now the next wave of efforts needs to be on universalizing these improved export controls. Specifically, enhancements would concentrate on verifying that the recipient has the capacity to handle safely and securely radioactive sources and that the shipper and any transfer shipping agents have bona fide credentials. Because the leaders at the Seoul Summit represent countries with major manufacturers of radioactive sources as well as major ports and shipping hubs, they can achieve significant improvements in export controls by tasking their governments to implement better controls and coordinate these efforts with other governments.

### *Increasing Government Cooperation in Intelligence Sharing About Threats*

Government to government cooperation and coordination are essential for understanding transnational terrorist groups that might exploit radioactive sources and for developing more effective international efforts to disrupt terrorists' plans for radiological attacks. For example, the Global Initiative to Combat Nuclear Terrorism (GICNT) includes the core principle of information sharing among the states that have voluntarily pledged to coordinate with each other. The GICNT began during the George W. Bush administration and has involved more than 80 states. At the Seoul Summit and beyond, leaders and their staffs should evaluate how to further share intelligence about the evolving threats.

### *Deploying Radiation Detectors and Other Means of "Second Line of Defense"*

If terrorists defeat security measures, they can obtain radioactive sources. But governmental authorities can still try to interdict transport of these sources. If the first line of defense is the security of the sources, the second line of defense then is to deploy methods of interdiction. The US National Nuclear Security Administration has created the Second Line of Defense program that works on: searching, detecting, and identifying nuclear and other radioactive materials at ports, border crossings, and other highly trafficked locations as well as developing response procedures and capabilities. The objective is to further deter or dissuade illicit trafficking of nuclear and other radioactive materials. While there is no guarantee that radiation detection systems will detect all such materials, the idea is to raise the costs for terrorists or other malicious people for trafficking these materials. The Second Line of Defense concept involves portal monitor for a first screening. Secondary inspection occurs if anything is detected in the primary screening. The collected data and intelligence about the threats are processed at national command centers. As an outstanding example of this type of program, the US government has worked closely during the past decade with several governments through the Megaports Initiative, which has focused on the world's largest ports and certain locations of high security concern. The Seoul Summit and future summits will provide opportunities for national leaders to discuss how to further expand second line of defense initiatives.

### *Rounding Up Disused and Orphan Sources*

Once a potent commercial radioactive source is no longer needed for its designed purpose, it often still has significant amounts of radiation. Thus, these “disused” sources can pose a security concern if not properly secured. If a source falls off the accounting books or registry or outside of regulatory controls, it is considered an “orphan” source.

In the United States, GTRI security experts have recovered more than 28,000 disused and unwanted sealed sources totaling over 814,000 Curies. But a backlog remains of more than 20,000 sources totaling 1,237,000 Curies registered for recovery.<sup>37</sup> One big concern is that the US Congress, faced with a growing US budget deficit, might cut funding for this program. The United States and several other governments have been funding over the past ten years programs to collect and secure thousands of disused and orphan sources in dozens of countries. While the focus of these programs was initially on the former Soviet Union, because of the relatively large number of potent disused and orphan sources, in recent years, such programs have expanded across the globe. The challenge for leaders at the Seoul Summit and in future international cooperative efforts is to ensure that there is a pool of money, equipment, and experts that is devoted to securing these types of sources.

### *Developing Improved Disposal and Recycling Pathways for Sources*

Disused and orphan sources need proper disposal pathways. Governments have the responsibility to develop and sustain disposal facilities. But establishing and maintaining these facilities are not easy tasks. Countries often lack the infrastructure required to handle radioactive waste. They may not have assured funding streams or escrow accounts to ensure long term maintenance of waste disposal facilities. To pay for the facilities, governments could charge user fees. But if the purchaser of a radioactive source was not originally required to pay such a fee, he may not have the several thousand to tens of thousands of dollars needed to pay for the transport and disposal costs of powerful disused sources. This situation could then lead to the owner of the source holding onto it for a long period during which the owner could go out of business or lose track of disused sources, potentially resulting in sources becoming orphaned. These are just some of the major problems that need to be addressed in disposing of disused sources. The IAEA has recently published a technical report that describes the problems and offers options for disposal.<sup>38</sup> While technical solutions are available, often the critical problem is political in nature. For example, publics do not want waste disposal sites near their neighborhoods. For the Seoul Summit and continuing international efforts, leaders should share their experiences with this vexing issue and examine ways for international cooperation on waste management.

### *Developing and Deploying Better Decontamination Technologies*

Radioactive contamination presents multiple challenges: economic, social, cultural, public health, and psychological. Governments, publics, and private owners will need to determine whether to demolish or decontaminate buildings taking into account the monetary, cultural, and historic values. For the decision to decontaminate, the methodology ranges from low impact mechanical techniques to high impact techniques to use of various types of chemical treatments. Specifically, these methods include vibratory processing, solution-grit blasting, power brushing, dry-blasting, manual wiping, foams, acids, chelants, and spalling. While the engineering and scientific experts can advise on these methods, the complex issue for national and local leaders is how to address the public’s justifiable concerns. Here again, leaders at the Seoul Summit and in the future need to ensure that their governments have developed plans that meet

the public's needs and that protect valuable property. This is an area ripe for international sharing of best practices.

### *Improving the Training of Emergency First Responders*

In the event of a radiological attack, the front line forces to mitigate the consequences will be emergency first responders including police, fire fighters, hazardous material experts associated with fire departments, and local medical personnel. The first few hours after a radiological incident are a critical time period in which efforts to care for injured people and initial cleanup and decontamination can make a big difference in saving lives, property values, and money. Consequently, it is vitally important that emergency first responders receive adequate training to handle radiological incidents. Fortunately, the IAEA has published the *Manual for First Responders to a Radiological Emergency*.<sup>39</sup> Leaders in Seoul and at future summits can direct their governments to avail themselves of this guidance document and also discuss mechanisms for effective cooperation among first responder communities in various countries.

### *Increasing the Capacity for Effective International Response to Radiological Incidents*

The Incident and Emergency Centre of the IAEA is the place to contact in the event of a nuclear or radiological incident or emergency. This center plays a global coordinating role in assisting states that are parties to the Convention on Assistance in the Case of Nuclear Accident or Radiological Emergency to make sure that states in need receive help from professionals trained in emergency response and other international agencies such as the World Health Organization. Also, the center helps with developing national response plans and applying standards and guidelines. Concerning the Seoul Summit and international efforts continuing after the summit, leaders should concentrate on urging the states that have yet to become parties to the Assistance Convention to do so as soon as possible. As of January 2012, 108 countries of about 190 are parties, while another 68 states have signed the convention with apparent intent to ratify or accede. Leaders should also ensure that the IAEA's center has adequate funds and resources.

These measures are individually imperfect defenses, but the combined effect of all of them would raise the barrier to radiological attack. The risk of radiological attack cannot be reduced to zero because substantial benefits are received from using radioactive materials safely and securely; however, the Nuclear Security Summit process and complementary international and national efforts can and should be used to further drive down this risk.

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