Nuclear and Radiological Terrorism: A Manageable Threat

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Abstract
The threat of a nuclear or radiological terrorist attack has become a consistent theme in news reports and popular media. But a comprehensive analysis reveals a real but limited threat, one that is manageable through intelligence, vigilance, and effective security culture. This article describes the limited parameters of the nuclear and radiological terrorist threat, and then describes various ways that the international community, nations and institutions are helping reduce the likelihood of such an attack.

Resumo
Terrorismo Nuclear e Radiológico: Uma Ameaça Gerível

A ameaça de terrorismo nuclear ou radiológico tem constituído um tema regular nos meios de comunicação social. Não obstante, uma análise abrangente revela uma ameaça real embora limitada, capaz de ser gerida por Serviços de Informações, ações de vigilância e uma cultura eficaz de segurança. Este artigo descreve não só os parâmetros limitados da ameaça do terrorismo nuclear e radiológico, como posteriormente expõe as diversas formas a partir das quais a comunidade internacional, Nações e instituições contribuem para uma diminuição da probabilidade de um ataque desta natureza.

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Introduction

In June 2014, the U.S. Senate Homeland Security and Governmental Affairs Committee held a hearing about the status of radiological security in the United States. The comments and debate focused primarily on the findings of a Government Accountability Office (GAO) report about the need for additional actions to increase the security of U.S. industrial radiological sources (GAO, 2014). Politicians and public commentators in America pounced on the alleged inadequacies of the Obama administration's security policies, predicting that doom and destruction was just around the corner. And recent highly publicized thefts of radiological source material in other countries underscored the concerns raised at the Senate hearing.

For example, in December 2013, an armed group in Mexico stole a truck containing cobalt-60 pellets (a radiological source used in hospital radiotherapy machines), generating headlines for several days until it was found abandoned in a field (Simpson, 2013). In May 2014, authorities in Ukraine apprehended a group of militants smuggling a radioactive source (thought to be uranium-235) in a makeshift container (Global Security Newswire, 2014b). In July, a truck transporting a container of iridium-192 (frequently used for industrial imaging purposes) was seized by thieves in a Mexico City suburb, but recovered a day later (Global Security Newswire, 2014a). And also in July, Sunni militants in Iraq seized 88 pounds of "low grade uranium" from a university in the northern city of Mosul.

However, in none of these cases were civilians in imminent or real danger. In the thefts in Mexico, the thieves very likely didn't even know what they were stealing (Romo, Parker and Castillo, 2013). And according to Olli Heinonen - the former chief inspector of the International Atomic Energy Agency (IAEA) - the low-grade uranium stolen by the Iraqi militants was unsuitable for use in a so-called "dirty bomb," which uses conventional explosives to spread radiation (Cowell, 2014). To be sure, there are reasons for concern and vigilance. The IAEA has investigated more than 20 cases of theft or loss of nuclear materials each year.[1] As IAEA spokeswoman Gill Tudor notes: "any loss of regulatory control over nuclear and other radioactive materials is a cause for concern" (Cowell, 2014). But a balanced, well-informed analysis of the threat is critical for devising successful responses to complex security challenges like terrorism and nuclear proliferation. In truth, despite the dramatic headlines and posturing of some politicians, the threat of

1 For example, see the summary compiled by Max Fisher and Richard Johnson for *The Washington Post*, published on December 5th, 2013, compiled from data provided by the IAEA Incident and Trafficking Database and Nuclear Threat Initiative. Available at http://www.washingtonpost.com/world/a-look-at-recent-nuclear-material-incidents/2013/12/05/c6f3edb6-5e17-11e3-be07-006c776266ed_graphic.html.

nuclear and radiological terrorism is both limited and manageable, for a number of often overlooked reasons that we will describe in this article.

To frame a more balanced analysis, we can begin with the U.S. Department of Defense's new *Strategy for Countering Weapons of Mass Destruction*, released in June 2014, which "seeks to ensure that the United States and its allies and partners are neither attacked nor coerced by hostile actors with weapons of mass destruction" (U.S. Department of Defense, 2014). The strategy articulates three primary areas of effort: preventing acquisition of WMD, containing and reducing the threat of existing WMD, and responding to WMD crises effectively. This timely document notes that the U.S. will "accept risk in areas where WMD use is implausible, infeasible, or would have limited effects so that resources can be focused on enhancing flexible response capabilities tailored to the most likely and operationally significant threats" (U.S. Department of Defense, 2014). Decades of scientific study on the effects of nuclear and radiological weapons has resulted in a clear understanding of what the most "operationally significant threats" are. However, the question of "most likely" has been subject to far more conjecture and speculation than factually-informed analysis.

Thus, in this article we examine the various technical, strategic and tactical dimensions of this question, concluding that radiological terrorism is considerably more likely than nuclear terrorism, and that the possibility of a radiological terrorist attack is limited within very narrow parameters. A terrorist group would require a perfect (and very rare) mix of resources, strategic rationale, opportunities and luck in order to successfully cross the radiological weapons threshold. Moreover, there are thousands of agencies, with hundreds of thousands of analysts and field agents, working every day to prevent such an attack. This is not an argument for complacency, but rather, an appeal to place the nuclear and radiological threat into a more appropriate - and less hyperbolic - perspective.

Nuclear and Radiological Weapons: A Quick Review

To begin with, not all commentators on these issues seem to understand that nuclear weapons and radiological weapons are much different from each other. Nuclear weapons are both extremely powerful and complicated to construct and store, especially by a non-State actor. They require fissile material - highly enriched uranium (HEU) or weapons-grade plutonium-239 - which can release massive amounts of energy in an uncontrolled chair reaction. Other candidate fissile materials considered potentially viable for nuclear weapons use include neptunium-237, americium-241 and reactor-grade plutonium. It is important to note that these fissile materials must be very pure and highly enriched (greater than 90 percent) for weapons use. Fissile materials are used in nuclear reactors at much lower enrichments (3-5 percent), where carefully controlled levels of fission produce energy for cities around the world. Nuclear reactors and nuclear weapons are fundamentally different in design. Nuclear weapons are designed to harness the release of fission energy for destructive purposes.

There are two basic kinds of nuclear weapon designs – gun-type and implosion. The former uses two carefully shaped concentrations of HEU, and a conventional explosion forces one into the other causing a chain reaction. Implosion weapons are far more difficult, requiring extremely precise engineering to ensure that all the small conventional explosive charges surrounding a sphere detonate at exactly the same nanosecond in order to compress the core of plutonium inside (otherwise, the device would function like a balloon popping, in which the plutonium core would be blown out of the device instead of causing the chain reaction).

Obviously, the key to nuclear weapons is the fissile material. Because access to HEU and plutonium-239 is constrained and regulated, states and terrorists face an enormous challenge acquiring this essential ingredient. As Graham Allison so eloquently argued a decade ago, the implications for global security are simple and clear: without fissile material, you cannot have a nuclear weapon (Allison, 2004). The difficulty in gaining access to fissile materials, as well as the very complex (and expensive) nature of these weapons in general, help explain why today only eight countries (China, France, India, North Korea, Pakistan, Russia, the UK, and the US) are officially recognized as nuclear powers (Israel is an additional, but "unofficial" nuclear power). Additionally, there are another 25 countries with more than 1 kg of weapons-usable nuclear material. Meanwhile, there are 186 other countries in the world who do not have nuclear weapons, and nearly all of those countries will never have them.

Compared to the fissile material needed for nuclear weapons, radiological sources are far more prevalent throughout the world. Radioisotopes - materials that emit radiation as they decay - are used in medicine to treat a wide array of cancers and other diseases. They are also found in various kinds of measurement instruments used in research and in a wide range of industries. Some radioisotopes can be used in weapons to make people sick through radiation exposure, depending on their half-life (the time during which the isotope decays, which determines the amount of radioactive energy released). Further, the radioactive source would need to be in a certain form to be useful in a weapon: think pellets, powder, or liquid, rather than the metals in which radioactive sources are sometimes stored.

In contrast to the nuclear weapons described above, there are no officially declared radiological weapons stockpiles. Within the past two decades, only one country - Iraq, under Saddam Hussein - pursued a radiological weapons program, and it was abandoned after the government came to realize that the enormous costs involved in making and maintaining such weapons would yield only modestly useful benefits. Further, according to a recent National Defense University report, no new technological developments regarding radiological weapons are foreseen (Caves and Carus, 2014).

Understanding the key differences between nuclear and radiological weapons is a necessary first step toward meaningful analysis of today's security challenges. A military-caliber nuclear weapon, stolen or otherwise acquired from a nation's stockpile, is considered by most analysts to be a highly unlikely terrorism scenario. This means there are three most likely types of weapons for terrorists to consider, listed here in order of decreasing complexity and difficulty: an improvised nuclear device (IND), a radiological dispersal device (RDD), or a radiological emission device (RED). As noted earlier, any kind of nuclear device requires fissile materials. Even a group of highly skilled, engineering-savvy terrorists might be able to fabricate a rudimentary gun-type weapons casing, they still face tremendous difficulty acquiring the right amount of fissile material, and in a form which allows them to manipulate and shape it to fit their weapons design. In contrast, a RDD requires radioactive materials of a suitable amount and in a format that can be dispersed via a conventional explosive, sprayer, or so forth.

And the least complicated of these types of weapons is the RED, which simply requires a type of radioactive source in virtually any form that can be placed discretely in a location which (the terrorists would hope) will over a period of time lead to radiation sickness among the victims before the weapon is discovered and disabled or removed. But even here, an RED requires the right kind of radioactive source: it must decay fast enough to produce high levels of radioactivity, but not become depleted so quickly that the victims are not exposed to enough radioactivity to cause the intended damage; it can be metals or liquids or other format, but must be in a shape and size that will not attract suspicion from the target; and it must be in a form that can be handled effectively by the terrorists and delivered to the target. Thus, even the simplest kind of radiological weapon is significantly complicated and difficult to deliver effectively.

To sum up, the technical aspects of these weapons are unique and extremely reliant on access to specific substances that are highly regulated and controlled. In recent years, a wide variety of books, movies and television shows have often portrayed terrorist groups easily acquiring and detonating a nuclear or radiological weapon. But the reality is that most terrorist groups could not—and in fact, most do not even want to - cross the nuclear or radiological weapons threshold.

The Terrorist Threat

At the outset, it must be emphasized that there have been very few terrorist plots involving radiological or nuclear weapons, and to date none of them have been successful. There is an extensive history of terrorist attacks over the past 120 years, perpetrated by a wide spectrum of groups and individuals: anarchists, left-wing and right-wing extremists, ethno-nationalists, religious extremists (including Zionists, Islamists, and violent opponents of abortion), environmental extremists, and many others. And yet, only a tiny fraction of these attacks have involved any kind of chemical, biological, radiological or nuclear (CBRN) materials. Further, as John Parachini has observed, even the rare incidents that involved the use of these kinds of weapons have hardly threatened mass destruction (Parachini, 2014).

According to the historical record, no terrorist group has even come close to having a nuclear weapon. Further, across the entire spectrum of terrorist, insurgents and other armed groups, only a small handful of militants in Chechnya have managed to assemble a rudimentary radiological weapon. During 1995 and 1996, Chechen militant leader Shamil Basayev made a series of threats to detonate radioactive containers in Russian cities, to target nuclear facilities in Russia, and even to explode a nuclear device. To support these ominous threats, he provided videos and photos displaying containers of radioactive materials (likely cobalt-60, cesium-137, or strontium-90), and told a Russian television network where to find a container of cesium-137 he had arranged to have buried in Moscow's Izmailovskiy Park (Bale, 2012). However, all of this fear-mongering and threats came to nothing: as of this writing, no radiological weapon has ever been successfully used by a terrorist or other violent non-state actor.

Of course, one could argue that the historical record is a poor judge of the future, given the extraordinary scientific and technical advances we see around us each year. Thus, to better understand the contemporary terrorist threat involving these weapons, we must examine the intentions of a particular terrorist group, and then examine the capabilities of that group (Forest, 2012). What we find in doing so is that among the hundreds of terrorist groups around the world, only a very small handful have any possible link to a radiological or nuclear threat.

Terrorists differ broadly in terms of intentions, resources and capabilities. We know a great deal about the intentions of terrorists because they tell us, through their ideological propaganda, what they want, and why they feel that violence is the only way they can get it. Terrorists use violence as a means to an end. They have objectives and goals, articulated in their ideologies, and believe that these can only be achieved through the use of violence. In most instances, the pursuit of power is central to their cause: power to shape the political future, power over a piece of territory (*e.g.*, ethno-national terrorists), power to assert racial dominance over others (*e.g.*, right-wing terrorists), power to change national policies (*e.g.*, anti-abortion, environmental, animal rights extremists), and so forth. When we unpack the details of terrorist groups within each of these ideological categories, we find that terrorists generally do not kill for the sake of killing. Further, analysis of terrorist manuals and interviews with incarcerated terrorist leaders reveal a common pattern of worrying about counterproductive violence. From the IRA to Hamas to al-Qaeda, we have seen terrorist group leaders condemn or try to reign in operatives whom they felt were engaged in activities that were so violent, they were jeopardizing the group's efforts to recruit and muster support among a target constituency.

Analysis of the broad spectrum of terrorist groups, both historical and contemporary, reveals that most terrorist groups have no interest in weapons of mass destruction, opting instead for more conventional weaponry in their attacks. Only a small handful have shown any indication that they would ever want a nuclear or radiological weapon. From this perspective, we come to understand more clearly, why concerns about radiological and nuclear terrorism may be exaggerated.

The important point to make here is that commentators who would have you believe that all terrorists are the same do not have a solid understanding of terrorism. To formulate effective counterterrorism efforts, especially pertaining to radiological and nuclear terrorism, we must understand who might want such weapons, and why. From decades of research on this question, most scholars and government analysts have concluded that only a very small proportion of the world's terrorists have any interest in crossing the radiological or nuclear threshold. Of these, most have similar tendencies: a religiously-based, typically apocalyptic ideology in which massive destruction creates an opportunity for a better world; a charismatic leader; a high level of paranoia; and a commitment to innovation and physical risk taking (Dolnik and Forest, 2012). Think Aum Shinrikyo (the Japanese cult responsible for the 1995 Sarin gas attack in the Tokyo subway) rather than any of the most well-known terrorist groups like Hamas, Hizballah, FARC or the IRA.

For a terrorist group considering any kind of attack, a considerable number of strategic, tactical and operational questions must be answered. For example: What kind of weapon do we want to use, and why? How will we acquire all the necessary materials? How will we afford it? Who in our group has the knowledge to construct this weapon? Where will we construct this weapon, and where will we store it securely until the time of delivery? How will we deliver the weapon to the target unhindered? Where? How can we test the weapon to see if it will actually work as planned? These and many other questions must be answered by the terrorist group as their plot unfolds. Bad decisions at any point along the way will jeopardize their chances of success.

The choice of weapon obviously impacts the nature of these questions. Whenever a terrorist group devotes its time, money and other resources toward an attack plan, they want to maximize the likelihood that their objectives will be achieved. And yet, terrorist groups are limited by what their members are capable of doing. Further, more complex terrorist plots have lower chances of success. Thus, a difficult and complicated nuclear or radiological weapons is seen as less desirable than the suicide bomb vest that has been tested and proven effective by terrorists in Sri Lanka, Lebanon, Iraq, Afghanistan, Israel and many other countries.

Properly handling and storing nuclear or radioactive materials is dangerous and requires sophisticated knowledge and skill, but virtually no terrorist groups have attracted competent radiological technicians or nuclear engineers. Further, even if a group does manage to overcome the significant technical challenges to build what they believe to be a viable nuclear or radiological weapon, they will likely be unable to test the weapon to ensure they have the correct design or delivery mechanism—again, raising the possibility that their attack plan will fail. In a sense, terrorist groups are somewhat risk-averse: their fear of failure can be a constraining factor in their decision-making. This is an often overlooked facet of terrorism threat analysis, one that should give us optimism about the future when it comes to nuclear and radiological terrorism.

Overall, there are many kinds of technical challenges associated with radiological and nuclear weapons, and these challenges influence a terrorist group's decision-making about whether to invest resources in trying to develop (or acquire) and use them. A group may want to use a nuclear weapon, but since no terrorist group to date has demonstrated the capability to make a nuclear weapon, their only other option is to acquire or steal one from a state. But under what conditions would a state give or sell a nuclear weapon to a terrorist group? While some hardcore right-wing politicians in the U.S. would have us believe otherwise, Iran, North Korea and Pakistan are governed by people who think strategically, and there is no doubt they understand that it would never be in their country's self-interests to willingly allow a terrorist group to have one of their nuclear weapons. The consequences of doing so would be catastrophic—not just for the victims of the terrorist attack, but also for the country that provided such a weapon. Given the sophistication of modern forensic science, states and terrorists have to consider the issue of attribution: following an attack involving a nuclear weapon, it is virtually assured that the international community will be able to identify the origin of the fissile material and the associated weapon. Condemnation and punishing attacks in retribution are highly likely.

It is doubtful that the leaders of any country – or their military leaders (which are more likely to have direct control over their country's nuclear arsenal) – can be considered suicidal. So, it strains credulity to imagine any country's leaders believing it would be in their best interests to provide a weapon to a terrorist group. Alternatively, could a nuclear weapon be stolen and then detonated by a terrorist group? The only likely scenario would require a significant amount of insider assistance, not only to acquire the weapon but also to bypass the safeguards used on all nuclear weapons worldwide. Combined with the fact that all nuclear-armed countries are determined not to let terrorists acquire and use one of their nuclear weapons, the odds are stacked against this kind of scenario. The possibility of theft or illicit trafficking of nuclear material is far more likely, and historical records show that there have been a number of incidents reported worldwide. As mentioned earlier, only a small number of countries have significant quantities of fissile materials. The facilities and materials in these countries are under strict safeguards and security regulations. There are enduring concerns about fissile material security in some countries due to political and economic instability, as well as inconsistency and lack of a global security standard. For example, numerous incidents of theft and illicit trafficking were reported between 1991 and 1999 in Russia and former Soviet Union states. The theft of nuclear material is partially related to security concerns associated with radiological sources, as discussed in more detail below.

In comparison to the threat of nuclear terrorism, a radiological terrorist attack is considered more likely. To begin with, there is a far more plentiful array of radiological sources used in medicine, research and industry worldwide. In the United States alone, radiological source materials are used by nearly 800 companies in over 1,400 facilities (Roth, 2014). A majority of these involve machines that use iridium-192 or cobalt-60, both considered "high risk" radiological source materials because they emit higher levels of radioactivity than most others. A U.S. government report released in June found that facilities using "high-risk industrial radiological sources" face challenges in (1) securing mobile and stationary sources (including radiography cameras used to test pipeline welds) and (2) protecting against an insider threat (GAO, 2014). An earlier report, released by the U.S. government in 2012, also identified weaknesses at U.S. medical facilities that use high-risk radiological sources, such as cesium-137 (GAO, 2012).

The most likely pathway to a terrorist attack involving a radiological weapon involves theft of a radiological source, and the most likely scenario in which such a theft could occur involves the assistance of someone employed at a facility where radiological sources are used. It is impossible to determine whether private sector facilities are less secure than government facilities, or vice versa. This is why rules that apply to workers at a government facility are the same for workers at private sector facilities. There are several types of scenarios in which a terrorist group could ensure the cooperation of an insider at a radiological source facility. There could be coercion (*e.g.* extortion, or holding a family member hostage), bribery, ideological indoctrination, or deception, among many others. The fundamental concerns associated with insider threat are relevant to both fissile and radiological material. Security at these facilities is obviously paramount to confronting the threat of radiological terrorism. There are also scenarios in which radiological source materials are seen as potentially vulnerable while in transit from one facility to another. The security concerns with fissile materials in transit are limited because the quantities and protocols are significantly different when compared to radiological sources.

And yet, similar to the nuclear weapons challenges identified earlier, the odds are stacked against the rare terrorist group that may have interest in acquiring these radiological source materials for use in a weapon. If you were the leader of such a group, you would need a significant amount of information on the facility where you might want to steal a radiological source; expertise on the proper storage and handling of radiological sources; detailed information on the size, weight, format (is it a powder, metal, liquid?), and other attributes of the radiological sources at the facility; and of course, information on the security procedures at the facility that are meant to ensure access to the radiological source for only authorized personnel. Further, the terrorists would need one or more individuals willing to take enormous risks in attempting to steal and handle radiological source material, and yet intelligent enough to evade security and not draw attention to themselves. If the theft was successful, the group would need a safe means of transporting the stolen radiological source to another location, one where it could be stored and manipulated into some kind of weaponized form - without the authorities and their radioactivity detectors tracking the group's activities and disrupting the plot.

It is true that detailed instructions and schematics for constructing radiological weapons can be found on the Internet in multiple languages. A relatively intelligent, skilled person equipped with these instructions, the right tools, and other resources may actually be able to design and construct the basic components of a weapon. But where will they find a radioactive source in a powdered form (for example), which could be dispersed in either an intentional release in a building's HVAC system or in an exploding "dirty bomb"? Many radiological sources used in medicine are in the form of pills, and radiological sources used in industry are often in the form of metals. Without a radiological source in the right physical form – powder, liquid, pellets, etc. – and emitting the right levels of radioactivity, the weapon would be incomplete. For example, the 88 pounds of low-grade uranium stolen in July from a university in Iraq was not really a weapons-related threat. As noted earlier, low-grade uranium is not useful for a nuclear weapon. Further uranium has a very long half-life, and thus the radiation it emits is very weak and would have a negligible effect if used in a radiological weapon (Oswald, 2014).

Meanwhile, as the terrorist plot grows in complexity, it requires the involvement of more individuals, risking the operational security of the group. The more people who know of a terrorist plot, the more likely one of them could become an informant for the police or government authorities. In sum, a variety of technical, strategic, tactical and operational challenges underscore the point made earlier: the more complicated the plot and the weapon, the less likely the chance of success. These challenges, coupled with the ideological and strategic constraints noted earlier, help explain why the true nature of the radiological or nuclear threat is limited to very few terrorists worldwide. Understanding the constraints faced by terrorists in the realm of nuclear and radiological weapons, in turn, can help us craft more targeted and effective counterterrorism and counterproliferation measures.

Strategies for Countering the Threat of Nuclear and Radiological Terrorism

The goals of the international community in dealing with this challenge are relatively straightforward: (1) deny the terrorists access to nuclear and radiological material, and (2) convince the terrorists that the use of such a weapon would be counterproductive to their ideological and strategic objectives. The second goal involves various forms of deterrence described in a recent report by the U.S. National Defense University: an unambiguous capacity to impose unacceptable costs on WMD-armed adversaries, an ability to attribute WMD attacks, and an ability to counter a WMD attack (*e.g.* through missile defense and homeland security measures) (Caves and Carus, 2014). Terrorists can indeed be deterred—we simply have to understand what the terrorist group holds dear, what it values most, and then demonstrate a capacity to have a negative impact on that (Kroenig and Pavel, 2012; Shapiro, 2013).

Much is being done in the realm of countering extremist ideology that is meant to deter a terrorist group from exploring the potential of nuclear or radiological weapons. But as Graham Allison succinctly noted over a decade ago, the most crucial area of effort is in preventing access to nuclear and radiological materials (Allison, 2004). Prevention requires a multifaceted effort that includes: (1) establishing security standards for all materials and sources, (2) reducing inventories, (3) detecting illicit transport through a global detection architecture and (4) human resource management – continuous training and monitoring the emotional and psychological well-being of those who have access to nuclear and other radiological material. There are a variety of national, regional and global efforts underway to address these issues. Perhaps the most well-known and globally reaching institution is the IAEA, established in 1956 to accelerate and broaden the peaceful use of nuclear energy, and to ensure - through inspection and verification - that the signatory countries of the Nuclear Nonproliferation Treaty (NPT) uphold the safeguards arrangements. The IAEA Department of Safeguards oversees the implementation of safeguards throughout the world. The safeguards system establishes legally binding agreements between nations and the IAEA pursuant to the commitments made under international and regional nonproliferation agreements. At the time of this writing there is no single authority or a legally binding agreement that comprehensively addresses the security of nuclear and radiological materials.

The role of the IAEA in ensuring security of the nuclear material is limited. For example, the safeguards agreements only apply to civilian facilities, in order to detect potential diversion of material for weapons use by a member state. They are not designed to provide physical security measures for the safeguarded facilities. The agreements also allow nuclear-weapon states to designate certain facilities as eligible for IAEA safeguards while excluding other facilities. Finally, the authority and budgetary resources of the IAEA constrain its ability to serve as the comprehensive nuclear security watchdog for nuclear and other radiological materials worldwide.

The IAEA and its member states have taken steps to support the effort that reduce the overall threat of nuclear and radiological terrorism. For example, the stockpiles of highly enriched uranium (HEU) and weapons-grade plutonium were initially the only materials considered by IAEA as materials of concern for nuclear weapon. In the early 1990s, Neptunium-237, Americium-241 and reactor-grade plutonium were also considered as materials that could be used for the fabrication of nuclear weapon. There has also been a growing recognition of the need to provide comprehensive security for industrial and medical radiological sources. The inventories of radiological sources are much more diverse in their composition and are found in a wide range of facilities around the world. Theoretically, some isotopes would be more useful than others for a radiological weapon. For example, Strontium-90, Iridium-192, Cesium-137 and Cobalt-60 are widely believed to pose a significant threat, due to their availability and their physical/chemical characteristics. These isotopes, along with many other potential candidate materials for radiological weapon, are used globally for research, medical applications, and industry. As a result, the protection, monitoring and reporting of illicit activities related to radiological sources has been a major challenge.

In 1995 the IAEA established an information system - the Illicit Trafficking Database (ITDB) - that archives incidents of illegal trafficking and unauthorized access of materials outside of regulatory control, as reported by participating countries.[1] As of December 2013, 125 countries participate in the ITDB program, collectively providing an authoritative source of information on the scope of the challenge worldwide - as IAEA Director General Yukiya Amano noted in 2013, "Over a hundred incidents of thefts and other unauthorized activities involving nuclear and radioactive material are reported to the [IAEA] every year" (Nuclear Threat Initiative, 2014: 6). Overall, the availability of materials, the lack of uniform border controls and detection architectures, and the diversity among the perpetrators engaged in these illicit activities illustrate the complexity of the problem.

The world's interest in nuclear energy has grown tremendously over the past decade. Nuclear power currently provides 16% of the world's electricity. There are 437 nuclear power plants installed in 31 countries, and an additional 68 are under construction in 15 countries, including Belarus, Indonesia, Jordan, Thailand and the United Arab Emirates. Approximately 60 countries have announced plans to adopt or increase the share of their nuclear power to meet their growing energy needs. Supporting expanded access to nuclear power must be balanced against the security concerns identified in this discussion.

In 2002, the IAEA Board of Governors approved a concerted Nuclear Security Plan along with a voluntary funding mechanism, the Nuclear Security Fund. Further

Nuclear Security Plans were approved in 2005 and 2009. More recently, the IAEA proposed and approved the Nuclear Security Plan 2014-2017. Through these efforts, the IAEA has identified a number of issues to address, cybersecurity, nuclear forensics and a need for a well-developed nuclear security culture and a comprehensive nuclear security system. Another international initiative is the 1980 Convention on the Physical Protection of Nuclear Material (CPPNM), which - along with its 2005 Amendment - is the only international legally binding agreement for the physical protection of nuclear material. The CPPNM is limited only to civilian nuclear material and does not include military or other non-civilian materials. These two broad categories of materials include nearly 85 percent of the global stocks of weapons-usable nuclear material that can be found in different forms at broad range of use and facilities.

Other international efforts to address nuclear and radiological security include the three Nuclear Security Summits - in Washington (2010), Seoul (2012) and The Hague (2014) - which brought heads of state from around the world together to address the dangers of nuclear and radiological materials proliferation. During these summits, world leaders committed to developing a global nuclear security architecture and reducing the stockpiles of nuclear and radiological materials. In addition to the removal of special nuclear materials and improved physical security at a number of facilities worldwide, the international efforts of the last half decade have also resulted in bilateral and multilateral agreements of cooperation on training and sharing of best practices.

Many nations have pursued their own bilateral and multilateral efforts to reduce global inventories of nuclear and radiological materials and to improve their security in response to terrorism concerns. During the 1990s and 2000s, Congress provided funding (via the Nunn-Lugar initiative) to help secure materials and facilities in former Soviet Union nations. Through its Global Threat Reduction Initiative, the U.S. has also led the effort to secure nuclear materials globally, set new security standards, and pursue partnerships with many countries to lock down sensitive materials. There are still concerns about certain facilities around the world that have less-than-adequate security of its nuclear materials, but the commitment to addressing these concerns has remained constant over the last several years.

There is also a significant need for nuclear security education and training. In addition to various programs offered by the IAEA, the organization also worked closely with experts and academics from member states to produce a guidance document for the development of educational programs in nuclear security. Finally, the IAEA hosts the International Nuclear Security Education Network, a partnership between IAEA, education and research institutions involved in nuclear security–related human resource development programs. In addition to IAEA efforts, non-profit organizations—like the world-renowned Nuclear Threat Initiative, the Institute for

Science and International Security, and the Center for Arms Control and Nonproliferation—have contributed to policy and public education, while a variety of academic institutions, like Harvard University's Belfer Center for Science and International Affairs and Stanford University's Center for International Security and Cooperation, have become influential sources for policy analysis and scholarship on nuclear and radiological security. At the University of Massachusetts Lowell (UML), two new initiatives - the Center for Terrorism and Security Studies (CTSS), and the Integrated Nuclear Security and Safeguards Laboratories (INSSL) - bring together subject matter experts with other global institutional partners for a variety of educational and training activities, including one-day workshops or week-long professional development courses on topics such as nuclear security culture, information security and cyber security, insider threats, international legal frameworks, radiation detection strategies and techniques, transportation security, nuclear and radiological forensics, and crime scene management. There is a need for both training that will fill knowledge gaps, and education—sustained programs that will establish a cohort of nuclear security experts as the demand for this expertise continues to grow globally.

As evident from this list of topics, nuclear security (and nuclear safeguards) is by nature a multidisciplinary field, requiring expertise in a variety of technical and social science disciplines. Practitioners in this field need to understand fundamental nuclear physics and engineering, material science, risk assessment, computational techniques, modeling and simulation, information technology, measurement techniques, and detector development. Those technical topics should be combined with social science topics such as political science, international relations, international law, energy policies, and regional studies. Faculty in UML's School of Criminology and Justice Studies are working closely with the faculty in the university's Nuclear Engineering program - whose radiation laboratories, nuclear research reactor, and strategic partnerships with Canberra Laboratories (the world leader in radiation detector development) - on development and delivery of education, training and research programs focused on nuclear security for the U.S. and international participants.

Specific research activities within INSSL include developing next generation radiation detectors that allow capabilities for field identification of radioisotopes, enhanced nuclear materials accountancy and surveillance techniques; equipping autonomous robots with detector systems that can communicate remotely and provide spectral information, GPS coordinates, and other information useful for efficient safeguards verification activities; and advanced computational tools for simulations of multiple scenarios for experimental validation. Together, these efforts at UML reflect the ways in which academic institutions are contributing to developing critical human resources for nuclear security, and by extension aiding in the global response to reduce the threat of nuclear and radiological terrorism.

Conclusion

From the global to the national to the institutional levels, there are many efforts and initiatives working in tandem to address the concerns of nuclear and radiological security. These efforts, in turn, are making it increasingly difficult for any terrorist group to believe they could successful conduct an attack using a nuclear or radiological weapon. Admittedly, the challenge is still a daunting one: according to a recent report by the Nuclear Threat Initiative, "there are nearly 2,000 metric tons of weapons-usable nuclear materials (highly enriched uranium, separated plutonium, and the plutonium content in mixed oxide fuel) stored at hundreds of sites around the world; some of those materials are poorly secured and are vulnerable to theft or sale on the black market" (Nuclear Threat Initiative, 2014). But as nations, international organizations, universities and other entities contribute to a comprehensive response to this threat, developing and sharing best practices in nuclear security and safeguards, optimism about the future is warranted.

Of course, security concerns involving nuclear or radiological weapons have become a part of our daily lives. The public sees daily representations of this threat in news reports of one kind or another, as well as in movies and television shows. However, these are sources of information in which drama is often emphasized at the expense of factual accuracy. As a result, the public discourse about the threat of nuclear or radiological terrorism is infused by a significant amount of misunderstanding and unfounded panic. Unfortunately, we see a similar pattern in the uninformed rhetoric of some political leaders as well. Yes, the threat of a nuclear or radiological terrorist attack is real, and if such an attack ever happens it would certainly have terrible consequences. However, while a sense of urgency is warranted, we must acknowledge all the limitations and caveats that are often overlooked in the public discourse. Importantly, most terrorists actually have not shown interest in these kinds of weapons. Further, it is highly unlikely that any nuclear-armed state would actually give or sell a nuclear weapon to a terrorist group. Radiological sources are more plentiful, and thus a radiological weapon is more likely than a nuclear one, but here too there are many limitations and parameters which constrain the threat.

The technical and operational challenges of making a nuclear or radiological weapon are extremely complex. Even if a terrorist group could overcome those difficulties, the central challenge remains of acquiring enough of highly constrained and regulated radiological or nuclear materials, and in the right form, for their weapon. In general, the global stockpile of nuclear materials is relatively small, and the worldwide locations and uses of those materials are accurately known, but this is not true for radiological materials. Efforts on the part of IAEA, countries, academe and the private sector will lead to new insights and more effective approaches to addressing these security issues. These efforts must include the development of nuclear security human resource development programs that are globally accessible. As more countries seek to develop peaceful uses of nuclear and radioactive materials, it is essential that they adopt nuclear security and safeguards into their plans.

In the end, there is no easy solution to the threat of nuclear or radiological terrorism. But the cumulative effect of the efforts described here - among many others - make it increasingly difficult that any terrorist group will have access to the essential materials for a nuclear or radiological weapon. The global movement to improve security and safeguards will make it virtually impossible for a terrorist group to successfully cross the nuclear or radiological threshold.

References:

Allison, Graham (2004). *Nuclear Terrorism: The Ultimate Preventable Catastrophe.* New York: Macmillan.

Bale, Jeffrey M. (2012). "The North Caucasus Conflict and the Potential for Radiological Terrorism" in James J. F. Forest and Russell Howard (eds.), *Weapons of Mass Destruction and Terrorism* (2nd edition). New York: McGraw-Hill, pp. 270-290.

Caves Jr., John P. and W. Seth Carus (2014). "The Future of Weapons of Mass Destruction: Their Nature and Role in 2030". *CSWMD Occasional Paper 10*.

Cowell, Alan (2014). "Low-Grade Nuclear Material is seized by Rebels in Iraq, UN Says". *The New York Times* (July 10). Available at http://mobile.nytimes.com/2014/07/11/world/middleeast/iraq.html.

Dolnik, Adam and James J. F. Forest (2012). "Conclusion: Appreciating the Past and Present, Anticipating the Future" in James J. F. Forest and Russell Howard (eds.), *Weapons of Mass Destruction and Terrorism* (2nd edition). New York: McGraw-Hill, pp. 753-765.

Forest, James J. F. (2012). "Opportunities and Limitations for WMD Terrorism" in James J. F. Forest and Russell Howard (eds.), *Weapons of Mass Destruction and Terrorism* (2nd edition). New York: McGraw-Hill, pp. 55-72

Kroenig, Matthew and Barry Pavel (2012). "How to Deter Terrorism". *The Washington Quarterly* nº2, pp. 21-36.

Nuclear Threat Initiative (2014). *Security Index: Building a Framework for Assurance, Accountability and Action* (2nd edition). Available at: http://ntiindex.org/wp-content/uploads/2014/01/2014-NTI-Index-Report1.pdf.

Oswald, Rachel (2014). "U.S. Downplays Extremist Seizure of Low-Grade Uranium in Iraq". *Global Security Newswire* (July 11). Available at http://www.nti.org/gsn/article/us-downplays-extremist-seizure-low-grade-uranium-iraq.

Parachini, John (2003). "Putting WMD Terrorism into Perspective." *The Washington Quarterly* nº4, pp. 37–50.

Romo, Rafael; Nick Parker and Mariano Castillo (2013). "Mexico: Stolen Radioactive Material Found". *CNN* (December 3). Available at http://www Castillo.cnn.com/2013/12/04/world/americas/mexico-radioactive-theft/.

Roth, Nikolas (2014). "Commentary on GAO Report on Radiological Security". Belfer Center, Harvard University (July 2). Available at http://nuclearsecuritymatters.belfercenter.org/blog/gao-report-radiological-security.

Shapiro, Jacob N. (2013). *The Terrorist's Dilemma: Managing Violent Covert Organizations.* Princeton: Princeton University Press.

Simpson, Connor (2013). "A Truck Filled with Radioactive Material Was Stolen in Mexico". *Global Security Newswire* (December 4). Available at http://www.nti.org/gsn/article/truck-filled-radioactive-material-was-stolen-mexico/.

U.S. Department of Defense (2014). *Strategy for Countering Weapons of Mass Destruction*. Washington D.C.

U.S. Government Accountability Office (2012). *Nuclear Nonproliferation: Additional Actions to Improve the Security of Radiological Sources at U.S. Medical Facilities.* Report GAO-12-925 (September). Available at http://www.gao.gov/assets/650/647931.pdf.

U.S. Government Accountability Office (2014). *Nuclear Nonproliferation: Additional Actions to Increase the Security of U.S. Industrial Radiological Sources.* Report GAO-14-293 (June). Available at http://www.gao.gov/assets/670/663917.pdf.