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E-NOTES

"A nation must think before it acts." - Robert Strausz-Hupé

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THE CASE OF POLAND'S STOLEN RADIOLOGICAL MATERIAL

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The translation of all source material is by the author unless noted otherwise.

"*The important measure is not the targets destroyed but rather the effect on the enemy's capabilities and actions.*"[1]

-David A. Deptula, USAF

"*I have destroyed him with the weapons I abhorred, and they are his. We have crossed each other's frontiers, we are the no-men of this no-man's land.*"

-John le Carré

On 6 March 2015, 22 canisters, each weighing 45kg-70kg (100-154lbs.) containing radioactive cobalt-60, were stolen from a Poznan warehouse on 6 March 2015.[2] The control of radiological materials in Poland is the responsibility of the National Atomic Energy Agency, known by its Polish language acronym, the PAA,[3] which reported the theft to the International Atomic Energy Agency on or around 19 March 2015.[4] On 10 March, Polish police arrested four persons (one of whom worked at the warehouse) and charged them with the 6 March theft. The same persons on 10 February stole about a ton of lead ingots from the same Poznan warehouse, which are used to build radioactive shields.[5] Poznan law enforcement authorities released this photograph of a canister similar to ones stolen on 6 March:[6]

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[1] BGEN David A. Deptula, USAF (2001). "Firing for Effects: the important measure is not the targets destroyed but rather the effect on the enemy's capabilities and actions." *Air Force Magazine*. 84 (April 2001), pp. 46-53.

[2] "Skradziono pojemniki z radioaktywnym izotopem" (""). *RMF24* [published online in Polish 8 March 2015]. http://www.rmf24.pl/fakty/polska/news-skradziono-pojemniki-z-radioaktywnym-izotopem,nId,1693008. Last accessed 19 March 2015.

[3] Polish: *Państwowej Agencji Atomistyki.*

[4] On the left: http://www-news.iaea.org/ErfView.aspx?mId=71bbf3df-b8b6-414a-81b8-6dc67a0d21e1. Last accessed 19 March 2015. On the right: "Trzy osoby zatrzymane w związku z kradzieżą pojemników z kobaltem" ("Three persons arrested in connection with the theft of canisters containing cobalt"). *Głos Wielkopolski* [published online in Polish 9 March 2015]. http://www.gloswielkopolski.pl/artykul/3778643,trzy-osoby-zatrzymane-w-zwiazku-z-kradzieza-pojemnikow-z-kobaltem,id,t.html?cookie=1. Last accessed 20 March 2015.

[5] *New Poland Express* [published online 15 Mrch 2015]. http://www.newpolandexpress.pl/polish_news_story-7183-.php. Last accessed 19 March 2015.

[6] Source: "Kradzież pojemników z promieniotwórczym izotopem kobaltu. Zatrzymany pracownik firmy" ("Theft of radioactive isotope canisters containing cobalt. Company employee arrested"). *RMF24* [published online in Polish 11 March 2015]. http://www.rmf24.pl/fakty/polska/news-

None of the stolen canisters has been recovered so far. They contain cobalt-60 pellets classified as category 4 and 5 radioactive sources (activity in the range 40 MBq-500 MBq as of 6 March 2015) with aggregated activity of about 7 GBq (see footnote).[7] While all radiation exposure poses a health risk, category 4 and 5 material is not dangerous so long as it remains within a radiation-shielding canister.

What poses a greater danger is the aggregate quantity of the radiological material stolen in Poznan. By the author's calculation, were the cobalt-60 pellets removed from their sealed metal casing[8]—the scenario in a December 2013 cobalt-60 theft in Mexico—anyone within 1 meter of the material would receive a lethal radiation dose in less than 4 minutes. The potential for malignant use is obvious, either to expose persons unwittingly to ionizing radiation, or to build several improvised radiological weapons.

Several months earlier, in May 2014, two lead canisters similar to those shown in the picture above and also containing cobalt-60 pellets were recovered from a scrapyard in Poraj, near Częstochowa in south central Poland's Silesia region.[9] The canisters were first discovered missing in November 2013 from the Belchatow Power Plant in Łódź. The canisters, which were used to measure the depth of waste ash reservoirs, had been in continuous service since 1992 and so the radioactivity of the cobalt-60 pellets contained within had substantially diminished.[10] And in December 2010, seven canisters were discovered missing from the defunct Ursus iron foundry in Lublin, where they were used to measure the depth of waste ash in storage tanks. The canisters were discovered missing during a routine inspection by Poland's National Atomic Energy Agency, which found that the foundry's "radiological protection supervisor had been fired and the documentation was missing."[11]

There is no suggestion in open-sources that any of the as-yet unrecovered canisters containing radioactive material from the 6 March theft or from earlier incidents are in the possession of a likely malefactor, nor is there any public information to lay basis to a claim that the canisters were stolen with the intent of weaponizing the radioactive material. That being said, the 6 March incident is by any estimation a major theft of radiological material, and indicative of a distressingly porous security regimen. While radiological threats have not been operationalized even if the capacities already exist, "they will emerge sooner or later or at all is for the future to decide; the only sure thing about the future is that something unexpected will occur."[12]

The risk of the theft by terrorists is self-evident and has been explored extensively, including by this author. A less explored iteration is the place of radiological weapons in hybrid warfare. That concept—*hybrid warfare*—describes attempts to gain an asymmetrical advantage over a purely conventional opponent within a specific environment.[13] It often combines with elements

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kradziez-pojemnikow-z-promieniotworczym-izotopem-kobaltu-zat,nId,1695885. Last accessed 20 March 2015.

[7] GBq is the abbreviation for *gigabecquerel*, which is 10^9 becquerel (Bq). A *becquerel* is defined as the activity of a quantity of radioactive material in which one nucleus decays per second. 37GBq is equal to one curie.

[8] Called a *cobalt capsule*, it contains cobalt disks, slugs or pellets grouped in a cluster or a solid cobalt cylinder, encased in a stainless steel capsule and sealed by welding.

[9] "W Poraju znaleziono pojemniki z radioaktywnym kobaltem" ("Canisters with radioactive cobalt found in Poraj"). *Gazeta Wyborcza* [published online in Polish 7 May 2014). http://czestochowa.gazeta.pl/czestochowa/1,48725,15917454,W_Poraju_znaleziono_pojemniki_z_radioaktywnym_kobaltem_.html. Last accessed 19 May 2015.

[10] Given (i) cobalt-60's half-life of 5.25 years, and (ii) when the canisters went into service [1992] and were identified missing [2014], the remaining activity of the cobalt-60 pellets contained within the canisters after four half-lives was approximately 6.25 percent.

[11] *New Poland Express* [published online in English 10 December 2010]. http://www.newpolandexpress.pl/polish_news_story-2671-.php. Last accessed 19 March 2015.

[12] Hâkan Gunneriusson (2012). "Nothing is Taken Serious Until it Gets Serious: Countering Hybrid Threats." *Defense Against Terrorism Review*. 4:1, p. 63. http://www.coedat.nato.int/publication/datr/volume7/04-Countering_Hybrid_Threats.pdf. Last accessed 20 March 2015.

[13] MAJ Timothy B. McCulloh, USA (2013). "The Inadequacy of Definition and the Utility of a Theory of Hybrid Conflict: Is the 'Hybrid Threat' New?"

of terrorism and criminal behavior,[14] leading to its prosaic description as "a perilous blend of the lethality of the state with the fanatical and protracted fervor of irregular warriors."[15]

Radiological weapons fit neatly into hybrid war doctrine:

> "Hybrid warfare is conducted by irregular forces that have access to the more sophisticated weapons and systems normally fielded by regular forces. Hybrid warfare may morph and adapt throughout an individual campaign, as circumstances and resources allow. It is anticipated that irregular groups will continue to acquire sophisticated weapons and technologies and that intervention forces will need to confront a variety of threats that have in the past been associated primarily with the regular Armed Forces of states."[16]

The traditional conflict spectrum resembles a number line with low-intensity conflict (e.g., counterinsurgency) on the far left and high-intensity (e.g., conventional and nuclear conflict) on the far right. That model is too simple to explain the complexities of hybrid warfare, however. Potential hybrid threats attempt (and sometimes succeed) to gain access to conventional military capabilities that normally reside closer to the middle of the conflict spectrum. Shawn Brimley of the Center for a New American Security has written that the proliferation of weapons of mass destruction (WMD) technology—radiological as well as nuclear, biological, chemical, and high explosive—has bent the high end of the conflict spectrum toward the middle.[17] This increases the probability that terrorists and hybrid threats intent on gaining gain access to this end of the spectrum will succeed at some point in doing so.[18] One scenario was described as decade ago in a discussion of a predecessor theory (to hybrid warfare), *Fourth Generation Warfare* (*4GW*):

> "A determined fourth generation warrior could either infiltrate into such a facility and steal [radiological or nuclear material] or obtain it by bribing officials. [While] theft of an actual nuclear weapon or fashioning an improvised nuclear device is possible...an adversary would need a great deal of expertise to fabricate a weapon or the proper codes to detonate a stolen weapon. A more likely use for the 4GW adversary is using this material in the fabrication of a RDD [Radiological Dispersal Device]. The extreme intensity and long half-life...would make for a physically and mentally devastating dirty bomb. Although weapon-grade uranium and plutonium are subject to close monitoring, other lower grade nuclear materials used in reactors and other commercial enterprises receive far less scrutiny."[19]

Radiological Weapons: A Primer

> *"Intellectually, it is possible to carry on the process [of believing things which we know to be untrue] for an indefinite time: the only check on it is that sooner or later a false belief bumps up against solid reality, usually on a battlefield."*
>
> -George Orwell

A grim tent of modern warfare is that the coming asymmetries will be radical. There will be no difference between operational area and civilian space, nor will the boundary between war and peace be well defined.[20]

Radiological weapons employed in terrorist and hybrid warfare inspired state-disruption are intended to disperse dangerous radioactive material and expose human populations to ionizing radiation,[21] causing panic and contaminating persons and

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In MAJ Timothy B. McCulloh, USA, & MAJ Richard Johnson, USA (2013). *Hybrid Warfare*. (MacDill AFB: The Joint Special Operations University Press), pp. 2, 9. http://jsou.socom.mil/JSOU%20Publications/JSOU%2013-4_McCulloh,Johnson_Hybrid%20Warfare_final.pdf. Last accessed 20 March 2015.

[14] Erik A. Claessen (2007). "S.W.E.T. and Blood: Essential Services in the Battle Between Insurgents and Counterinsurgents." *Military Review* (November-December 2007), pp. 92-93. Cited in McCulloh (2013), p. 12.

[15] Frank G, Hoffman (2007). *Conflict in the 21st Century: The Rise of Hybrid Wars.* (Arlington, VA: The Potomac Institute for Policy Studies), p. 37.

[16] Hybrid Warfare Panel Discussion, 9 February 2012, Fort McNair, DC. Quoted in McCulloh, *op cit.,* p. 10.

[17] See for example: Shawn Brimley (2009). "Crafting Strategy in an Age of Transition." *Parameters.* Winter 2008-2009, pp. 27-42. http://strategicstudiesinstitute.army.mil/pubs/parameters/Articles/08winter/brimley.pdf. Last accessed 20 March 2015.

[18] These ideas are developed further in COL Jeffrey L. Cowan, USAF (2009). *A 'Full Spectrum' Air Force*. (Maxwell AFB: Air War College).

[19] MAJ Julian M. Chesnutt, USAF (2003). *Defeating the United States with Radiological Weapons in Fourth Generation Warfare*. (Maxwell AFB: Air University), pp. 19-20. [author's copy]

[20] *Ibid.,* p. 67.

[21] In addition to acts of terrorism that by definition are perpetrated by non-state actors, radiological weapons also have a place in so-called *Fourth Generation Warfar*e or *4GW*. One goal is to "collaps[e] the enemy internally rather than physically destroying him. Targets will include such things

property. There are two types of radiological weapon. The first incorporates radioactive material into a device designed to disperse it into the environment. This type is called a *Radiological Dispersal Device* (*RDD*).

There are explosive and non-explosive RDD iterations. An *Explosive Radiological Dispersal Device* (*E-RDD*)—known informally as a "dirty bomb"—uses the energy generated by the detonation of a conventional explosive to cause the shock aerosolization of radioactive material .[22] An E-RDD does not derive its energy from a nuclear fission reaction and so is not a "nuclear bomb."

In addition to injuries (mostly physical trauma and thermal burns) and property damage that result from the explosion's kinetic effect, the detonation of an E-RDD causes radioactive material to aerosolize and disperse into the atmosphere. This leads to *radiation exposure*—radiation penetrating living tissue—from contact with aerosolized radioactive material in the air or on the ground (the latter known as *groundshine*). There are two subcategories of radiation exposure. The first, *rate of exposure*, is the amount of radiation that is received by an object per second. The second, *cumulative exposure* (*aka* "dose") is the total amount of radiation received or absorbed. A short exposure to a highly radioactive source can be as damaging as a long-term exposure to a mildly radioactive one. The dispersal of aerosolized radioactive material also leads to *radiation contamination*. This can be *external contamination*—when aerosolized radioactive material settles on clothing, hair, or skin—and/or *internal contamination*—aerosolized radioactive material entering the body by means of inhalation, ingestion, and/or absorption through the skin or wounds.[23]

While there are military-grade E-RDD designs, an improvised device is far more likely in the context of terrorism—there are technical challenges and practical constraints associated with fabricating a radiological weapon—and hybrid warfare—principally to conceal the aggressor-state's role. On the other hand, access to explosives is widespread: explosive materials are in common commercial use, and an improvised conventional explosive can be easily formulated from unmonitored materials such as nitrogen fertilizer and diesel fuel. Commercial radioactive material regularly moves unguarded and the many incidents of theft and diversion make clear that a determined malefactor could obtain both the explosive and the radioactive material necessary to fabricate an improvised E-RDD.

Another type of RDD employs non-explosive means to disperse radioactive material into the environment—for example, by contaminating food, water, soil or air—in order to expose a modest number of people to moderate doses of radiation, and/or many people to low doses of radiation. This type of device is known as a *Non-Explosive Radiological Dispersal Device* (*N-RDD*). Its principle advantage is that and N-RDD may emit radiation undetected for extended periods. Given, however, that the disruptive effect of terrorism is a function of an event's "shock" effect on the target population, it is more likely a terrorist would use an explosive rather than a non-explosive device.

The second means of exposing human populations to dangerous radiological material for the purpose of terrorism is a *Radiation Exposure Device* (*RED*). An RED consists of an unshielded sealed source of ionizing radiation, and so is a much simpler device than an RDD. In the context of terrorism, an RED would be placed in a public venue to which a large number of people have access and would be unwittingly exposed to ionizing radiation.

Isotopes well suited to the construction of RDDs and REDs are identified in the table below. For each isotope, data are shown for how sources exist within Poland by-category as well as the human health hazard(s) associated with the isotope.

(Table appears on the following page)

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as the population's support for the war and the enemy's culture. Correct identification of enemy strategic centers of gravity will be highly important." See: William S. Lind; COL Keith Nightengale, USA; CAPT John F. Schmitt, USMC; COL Joseph W. Sutton, USA; & LT Colonel Gary I. Wilson, USMCR (1989). "The Changing Face of War: Into the Fourth Generation." *Marine Corps Gazette*. October 1989, pp. 22-26

[22] A given radiological material is conducive to aerosolization depending upon its specific thermal and mechanical properties. As much as 80 percent of the original material can be aerosolized by means of an E-RDD if the material properties are conducive to aerosolization and a sophisticated explosive device is used. See: Frederick T. Harper, Stephen V. Musolino & William B. Wente (2007). "Realistic radiological dispersal device hazard boundaries and ramifications for early consequence management decisions." *Health Physics*. 93:1, p. 5. http://www.ncbi.nlm.nih.gov/pubmed/17563488. Last accessed 18 March 2015.

[23] Since radiation exposure does not require contact with radioactive material, an exposed person is not necessarily contaminated. However, as long as a person remains contaminated, they will continue to be exposed to the radiation emitted by the radioactive material with which they are contaminated.

Select Radioactive Isotopes & Sources by Category.[24]

Isotope		Half-Life[25]	No. Sources in Poland				Health Hazard		
			Category[26]				High-Energy Alpha Emissions[27]	High-Energy Beta Emissions[28]	High-Energy Gamma Emissions[29]
			I		II	III			
Name	Symbol		No. Sources	Sources[30]					
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Americium-241	Am-241	432 yrs.	2		413	973	YES	NO	LOW
Cesium-137	Cs-137	20 yrs.	69	I, SSI, BTI, T	338	2221	N/A	LOW	YES
Cobalt-60	Co-60	5.27 yrs.	561	I, SSI, MBT, T	1171	2633	N/A	LOW	YES
Iridium-192	Ir-192	74 days	222		42	1	N/A	YES	YES
Plutonium-238	Pu-238	87.7 yrs.	0		77	19	YES	NO	LOW
Plutonium-239	Pu-239	24100 yrs.	3		122	106	YES	LOW	LOW
Radium-226	Ra-226	1600 yrs.	0		80	63	YES	NO	LOW
Strontium-90	Sr-90	28.8 yrs.	1		19	852	N/A	YES	N/A

25 26 27 28 29 30

Of these eight (8) isotopes, four (4) meet criteria of widespread commercial use (and thus are available for diversion), sufficient radioactivity and long half-life, and so are most likely to be used in a radiological weapon. They are americium-241 (Am-241),

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[24] The data source for columns (3) through (6) is Poland's National Atomic Energy Agency/PAA (2012). *Activities of the President of National Atomic Energy Agency (PAA) and Assessment of Nuclear Safety and Radiological Protection in Poland In 2012*. (Warsaw: National Atomic Energy Agency), p. 37. http://www.paa.gov.pl/sites/default/files/raportPAA2012ang.ostateczny.pdf. Last accessed 18 March 2015. The data source for columns (7) through (9) is the International Atomic Energy Agency (2003). "Categorization of Radioactive Sources." IAEA-TECDOC-1344 (4 July 2003). http://www-pub.iaea.org/MTCD/publications/pdf/te_1344_web.pdf. Last accessed 15 March 2015.

[25] Half-life is the time necessary for a radioactive material to decay to one-half of its original activity.

[26] There are five categories within the categorization system established by the International Atomic Energy Administration, within which Category 1 sources are considered the most dangerous because they can pose a very high risk to human health if not managed safely and securely.

[27] An alpha particle is a relatively heavy, high-energy particle that, if inhaled, ingested (swallowed), or absorbed into the blood stream, can cause biological damage to living tissue that increases the risk of cancer. In particular, alpha radiation is known to cause lung cancer in humans when alpha emitters are inhaled.

[28] A beta particle is a particle with an electrical charge of -1. Beta particle emission occurs when the ratio of neutrons to protons in the nucleus is too high. An excess neutron transforms into a proto4n and an electron. The proton stays in the nucleus; the electron is ejected energetically, and can travel several feet in open air until stopped by a solid material. Beta radiation can cause cancer and other chronic health effects as well as acute health effects (though these are less common). Chronic health effects result from low-level exposures over a long period of time and develop relatively slowly (5-30 years).

[29] Gamma radiation is very high-energy ionizing radiation in which the nucleus ejects a gamma photon (pure electromagnetic energy in the form of gamma radiation) to become more stable. Most exposure is direct external exposure since gamma radiation can easily travel great distances through air and penetrate several centimeters in tissue, passing through the body and exposing all organs. While generally classified as an external hazard, gamma emitting radionuclides can also be inhaled, or ingested with water or food, and cause exposures to organs inside the body. Depending on the radionuclide, they may be retained in tissue, or cleared via the urine or feces.

[30] Key:
RTG= Radioisotope thermoelectric generators. An RTG converts the waste heat given off by radioactive decay processes into useable electrical energy. It uses an array of devices called *thermocouples*, which convert thermal energy directly into electrical energy.
I= Irradiators used in sterilization and food preservation.
SSI= Self-shielded irradiator. A self-shielded irradiator is a self-contained device in which the shielding required for operation is an integral part of the device, and the irradiation chamber is not accessible during operation. SSIs are used to irradiate a wide range of products and materials.
BTI= Blood/tissue irradiators. A BTI is a type of SSI. Most use Cesium-137 because of its long half-life, relatively low cost, and relatively modest shielding requirements, which make it possible to place a device in hospitals and blood banks.
MBT= Fixed multi-beam teletherapy, i.e., gamma knife.
T= Teletherapy sources. Teletherapy is also known as External beam radiotherapy (EBRT)

cobalt-60 (Co-60), iridium-192 (Ir-192), and strontium-90 (Sr-90), respectively. Each has been implicated in known incidents involving theft or misuse.

The incident in Poland should renew attention on the misuse of cobalt-60 in a Radiological Dispersal Device or a Radiological Exposure Device.[31] Cobalt is a hard and brittle metal, gray in color with a bluish tint. Its most common radioactive isotope is cobalt-60 (Co-60), which is produced by exposing the stable form of cobalt, cobalt-59, to neutron bombardment in a nuclear reactor for a period of 12 to 18 months. Under normal pressure and temperature, cobalt-60 is a solid with magnetic properties similar to those of iron. Cobalt-60 in the form of disks, slugs or pellets grouped in a cluster or a solid cobalt cylinder is typically encased in a stainless steel capsule and sealed by welding; the capsules are then incorporated into devices like medical linear accelerator.

While much of the recent focus on Russian hybrid warfare in its near abroad has focused on the cyber aspects of a conflict (i.e., *cybered conflict* rather than a purely cyber one), hybrid warfare is an ideal domain for radiological weapons. The theorized fabrication of a radiological weapon of one sort or another begs the question how such a weapon might be used in terrorism or hybrid war. Effects-based targeting dictates the selection of a site to detonate an E-RDD, or to place of an N-RDD or RED, since the purpose is to evoke a powerful psychological response. This stems from the perceived "open-ended" nature of the threat; the chronic state of alarm associated with the fear of radiation exposure and radiation contamination; and the fact that "nuclear" events (not in fact, but in popular perception) are the most dreaded of all human catastrophes.[32]

Sealed-source cobalt-60 RDDs are associated with the most drastic effects on human populations and the environment. Models simulating RDD detonation-dispersion-deposition evince that even an unsophisticated embodiment can have meaningful consequences. For example, detonating an RDD with a small submunition (10 lbs. of TNT) in a metropolitan area on a relatively calm day (wind speed <1mph) would send aerosolized radioactive "ballistic particles" downwind in a cloud, exposing persons within a five block area (250 meter radius) from the point of detonation to internal and external contamination.[33] The most serious health effects would occur within the detonation point's immediate radius (23 meters for a small submunition; 385 meter for a large one) and to those caught in the downwind plume up to 60 meters of the detonation point.[34] The radiation plume would likely contaminate an additional 40 square block area.[35]

Concluding Thoughts

General Mieczysław Gocułsaid, Chief of the General Staff of the Polish Army, said during a recent meeting with his Lithuanian counterpart in Vilnius:

> "Soldiers must be ready for bad weather. And that bad weather, in particular, means little green men...I have no doubt that both the Lithuanian and Polish armed forces are ready for that."[36]

Deferring to General Gocułsaid's judgment, it is nonetheless difficult to reconcile Poland's self-perceived preparedness to counter a Crimea-like scenario with—if not shockingly poor, then highly variable—custody of potential weapons-stock radioactive material for an improvised radiological weapon.

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[31] It could just have easily have focused on other radioactive materials of choice given the number of incidents of theft reported in 2014, including: in October 2014, category 3 Am-Be185 in Peru; September 2014 incidents in Kazakhstan

[32] National Council on Radiation Protection (2001). *Management of Terrorist Events Involving Radioactive Material.* NCRP Report No. 138. (Bethesda, MD: National Council on Radiation Protection), pp. 50-55. These effect were observed, for example, in a 1987 incident in Goiânia, Brazil, involving accidental radiological contamination from the misuse of a radiotherapy device containing cesium-137. The source-capsule ruptured as the device was dismantled for scrap by local residents, who found the abandoned unit in a partially demolished building..

[33] While this effect is serious enough, most simulations postulate assume larger submunitions, for example, 50 lbs. of hand-carried TNT and 500 lbs. carried in an automobile.

[34] United States Air Force (2011). *Operations in a Chemical, Biological, Radiological, Nuclear, and High-Yield Explosive (CBRNE) Environment*, pp. 260 & 278. http://static.e-publishing.af.mil/production/1/af_a3_5/publication/afman10-2503/afman10-2503.pdf. Last accessed 20 March 2015.

[35] Cristina Alice Margeanu (2010). "Comparative Study on Radiological Impact due to Direct Exposure to a Radiological Dispersal Device using a Sealed Radiation Source." Paper presented to the Tenth Radiation Physics & Protection Conference, 27-30 November 2010, Nasr City-Cairo, Egypt. http://www.iaea.org/inis/collection/NCLCollectionStore/_Public/42/076/42076656.pdf. Last accessed 20 March 2015.

[36] "Lenkijos kariuomenės vadas Vilniuje: esame pasirengę „žaliesiems žmogeliukams"." ("Polish army chief in Vilnius: We're ready for 'little green men'."). *DELFI* [published online in Lithuanian 5 March 2015]. http://www.delfi.lt/news/daily/lithuania/lenkijos-kariuomenes-vadas-vilniuje-esame-pasirenge-zaliesiems-zmogeliukams.d?id=67353114. Last accessed 20 March 2015.

The future security environment will be shaped by expanded access to destructive technology and tactics by smaller non-state groups and individuals.[37] Thus it is dangerous to stereotype an adversary as incapable of certain capacities, for even improvised radiological weapons can deliver "violence in volume,"[38] in Gunneriusson's memorable phrase. The mass availability of dangerous radiological material is the most striking feature of this threat and makes it dynamic. And the admixture of mass availability and a determined terrorist or hybrid warrior makes the situation unpredictable. It is critical to have a full understanding of the threat posed by unsecured radiological material, for like all hybrid threats, they expand the spectrum in ways that are most dangerous.

[37] Paul Scharre (2012). "Trends in Hybrid and Irregular Warfare." *Proceedings Magazine*. 138:9/1 (September 2012). http://news.usni.org/2012/09/27/trends-hybrid-and-irregular-warfare. Last accessed 20 March 2015.

[38] Gunneriusson (2012), *op cit.,* p. 50.