



Threat Convergence: New Pathways to Proliferation?

Expert Series

The Economics of Nuclear Terrorism

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Another scheme revealed that [Usama] Bin Ladin sought the capability to kill on a mass scale. His business aides received word that a Sudanese military officer who had been a member of the previous government cabinet was offering to sell weapons-grade uranium. After a number of contacts were made through intermediaries, the officer set the price at \$1.5 million, which did not deter Bin Ladin. Al Qaeda representatives asked to inspect the uranium and were shown a cylinder about 3 feet long, and one thought he could pronounce it genuine. Al Qaeda apparently purchased the cylinder, then discovered it to be bogus. But while the effort failed, it shows what Bin Ladin and his associates hoped to do. One of the al Qaeda representatives explained his mission: "It's easy to kill more people with uranium."

Final Report of the National Commission on
Terrorist Attacks Upon the United States

Bin Laden's evident interest in acquiring highly enriched uranium is deeply troubling. The attempt to purchase highly enriched uranium belies a piece of conventional wisdom first articulated by Brian Jenkins – "Terrorists want a lot of people watching, not a lot of people dead."¹

Clearly, some terrorists *do* wish a lot of people dead. Far from an isolated incident, al Qaeda operatives made a number of efforts to acquire nuclear materials over the years: Bin Laden sought a fatwa in 2003 permitting the use of weapons of mass destruction and called the acquisition of weapons of mass destruction (WMD) a "religious duty"; al Qaeda operatives have tried to recruit nuclear weapon scientists and extensive documents, including crude bomb designs, were found in Al Qaeda training camps in Afghanistan.²

¹ Brian Michael Jenkins, "International Terrorism: A New Mode of Conflict" in David Carlton and Carlo Schaerf (eds.), *International Terrorism and World Security* (London: Croom Helm, 1975), p. 15. For a more recent statement of this hypothesis, see Robin M. Frost, *Nuclear Terrorism After 9/11*, Adelphi Paper 378, London, UK: International Institute for Strategic Studies, 2005.

² David Albright, *Al Qaeda's Nuclear Program: Through the Window of Seized Documents*, Nautilus Institute Special Forum 47, November 6, 2002. Available: http://www.nautilus.org/archives/fora/Special-Policy-Forum/47_Albright.html. See also, Matthew Bunn, Anthony Wier, and Josh Friedman, *The Demand for Black Market Fissile Material*, June 16, 2005.. Available at: http://www.nti.org/e_research/cnwm/threat/demand.asp

Other authors have demonstrated the plausibility of improvising a nuclear device, given the nuclear explosive material (NEM). But scholars have expended comparatively little effort to estimate the scope and cost of such a project and, therefore, to determine whether, as a practical matter, terrorists would find the use of nuclear explosions to be a “cost effective” means to inflict very large numbers of casualties.

Comparing Conventional and Nuclear Terrorism

Would and could terrorists build a nuclear device? One way to answer the question is to determine how costly building a nuclear device would be, particularly in comparison to other methods for inflicting large numbers of casualties. The simplest model begins with the assumption that terrorist organizations interested in inflicting large numbers of casualties, such as al Qaeda or Aum Shinrikyo, want to maximize casualties and minimize costs.

The *United Nations Monitoring Team concerning Al Qaida and the Taliban* has published basic information about the cost of various attacks by al Qaeda.³ Very similar attacks, of course, may result in widely different casualties depending on the target. For example, the bombing of the Marriot Hotel in Jakarta killed a relatively small number of people compared to the 2002 Bali bombings, despite relatively similar devices.

Despite such variation, we see some support for the hypothesis that the relationship of cost and casualties follows a simple curve, with the cost per casualty inflicted increasing as the size of terror attacks increases—from the relatively inexpensive Madrid bombing (which cost less than \$10,000 or around \$50/murder) to the World Trade Center (which cost \$400,000-500,000 or \$180/murder). It is difficult to conceive of a terrorist attack with conventional weapons more deadly than on the order of 10,000 people killed, suggesting that the curve asymptotically approaches this number. Conventional attacks that killed 100,000 people at a time would be prohibitively expensive, and, most likely, impossible.

Mass casualties can also be inflicted with biological or, conceivably, chemical weapons⁴ The sophistication of a truly mass casualty attack with chemical or biological weapons is much harder to estimate. In particular, we wonder about the ability of terrorists groups to handle

³ *Letter dated 23 August 2004 from the Chairman of the Security Council Committee established pursuant to resolution 1267 (1999) concerning Al-Qaida and the Taliban and associated individuals and entities addressed to the President of the Security Council containing the FIRST REPORT of the MONITORING TEAM pursuant to resolution 1526 (2004), S/2004/679, August 25, 2004, pp.12.*

⁴ It is considerably simpler to build a small biological or chemical capability than a useful nuclear one. Still, we believe that *mass casualty* biological or chemical attacks would be more difficult than constructing a simple nuclear weapon. For the vast majority of chemical agents, the number of casualties would probably be an order of magnitude lower than from a nuclear blast and very large amounts of agent would also be required. A few biological agents have the potential to kill as many people as a nuclear weapon. But extremely dangerous pathogens are rarer and better guarded than fissile material – better guarded because they are extremely difficult to handle. We do not dismiss the danger of such attacks, however, and welcome other scholars to consider application of our model to chemical or biological attacks.

extremely dangerous pathogens. In principle, however, one could apply this model to such attacks as well, although we have chosen to emphasize a nuclear attack.

A terrorist, of course, might claim that a simple “cost per casualty” model fails to capture the essentially political end of his or her organization. Some terrorists prefer attacking a high-profile, better protected target that produces fewer casualties but with the victims concentrated among foreign diplomats or military personnel—for example a US embassy or naval vessel. Others may prefer a nuclear attack, irrespective of the number of casualties, given the fear that such weapons induce. The willingness of an organization to pay for different attacks reveals underlying preferences, such as the rate at which a group like al Qaeda, is willing to trade civilian casualties for attacks against high profile targets.

For our purposes, we wish to inquire, for an organization like al Qaeda, whether a nuclear weapons attack would be cost effective at the margin. A terrorist attack that killed 100,000 people for a cost of \$10 million dollars—about \$100/murder—would be a bargain for terrorists, given the large number of attacks that al Qaeda mounted in the \$100-300/murder range. A nuclear terrorist attack that cost \$5 million would result in a cost per murder comparable to the Madrid bombings. As the United States and its allies make prudent investments in defensive measures against conventional terrorist attacks, the cost effectiveness of nuclear attacks would increase.

The simple appeal of nuclear terrorism can be illustrated with a thought experiment. Not only would 10,000 persons represent the theoretical limit of a conventional terrorist attack, but that figure exceeds the combined casualties in all of al Qaeda’s attacks over the entire history of the organization. Even a failed nuclear detonation, one that produced a few tens of tons in yield, in the appropriate location, would kill 10,000 people, by blast and fallout, in a few hours.

Modeling the Cost of Nuclear Terrorism

This section is treated in more detail in: Peter Zimmerman and Jeffrey Lewis, The Economics of Nuclear Terrorism, Harvard University Managing the Atom/King’s College London Centre for Science & Security Studies Joint Working Paper, August 2006.

In our scenario, terrorists construct the nuclear device in the United States, rather than attempting to smuggle it fully constructed across the border. Even in the case of a smuggled device, several operatives, including the most technically gifted members of the plot, would have entered the United States to oversee the final check-out, assembly and delivery of the device. Smuggling additional plotters, who need not know their purpose until arrival at the location, seemed a small risk when compared to the difficulty of acquiring furnaces, lathes and other specialized machinery abroad. We recognize that terrorist groups might make a different decision.⁵

⁵ This scenario draws heavily on the fictional account presented in Nicolas Freeling, *Gadget* (London, UK: Heinemann, 1977 and House of Stratus reprint, 2001). Peter Zimmerman is the unnamed physicist who worked with Freeling on the book.

Most observers agree that a small group could construct a crude nuclear device. In 1977, the Office of Technology Assessment estimated that, provided with fissile material, a “small group of people” including a “person capable of searching and understanding the technical literature in several fields and a jack-of-all-trades technician” could complete a crude nuclear device for a sum that “need not exceed a fraction of a million dollars.”⁶

Given the goal of building a bomb capable of killing 100,000 people for less than \$10 million, we see no reason for an organization much like al Qaeda before it was severely disrupted to attempt such a bargain basement operation. The constraint we have placed on our would-be bomb-makers is a cap at 19 persons working over the course of a year in the United States. Recent events suggest the plausibility of a conspiracy of this scope and duration. As can be seen in the table of expenditures, the project employs some 15 to 17 people full time for about one year. The entire active team numbers no more than the 19 hijackers involved in the 9/11 plot.

Figure 4: Summary of Expenditures by Category

Physics and Computation

Senior Leader	100,000 at 1 year	100,000
2 Postdoctoral Students	50,000 at 1 year	100,000
<i>Physics and Computation Subtotal</i>		<i>200,000</i>

Metallurgy and Casting

3-4 Personnel		200,000
Vacuum Furnace		50,000
Other equipment including crucibles, etc.		20,000
<i>Metallurgy and Casting Subtotal</i>		<i>270,000</i>

Precision machining and construction

3-4 Personnel		200,000
Precision Lathe		10,000
Supplies, expendables and other tools		20,000
<i>Precision machining and construction Subtotal</i>		<i>230,000</i>

⁶ Office of Technology Assessment, *Nuclear Proliferation and Safeguards*, Washington, DC: Government Printing Office, 1977. 1 million dollars in 1977 is worth about 2.75 million dollars today. Mark *et al* estimate that “the number of specialists required would depend on the background and experience of those enlisted, but their number could scarcely be fewer than three or four and might well have to be more.” J. Carson Mark, Theodore Taylor, Eugene Eyster, William Maraman, and Jacob Wechsler, *Can Terrorists Build Nuclear Weapons?*, Paper Prepared for the International Task Force on the Prevention of Nuclear Terrorism, 1986. Available at: <http://www.nci.org/k-m/makeab.htm>

<u>Gun Design, assembly and testing</u>	
3-4 Personnel	200,000
Recoilless Rifle	10,000
Supplies and expendables	20,000
<i>Gun Design, assembly and testing Subtotal</i>	<i>230,000</i>
<u>Electronics, safing arming, fuzing and firing</u>	
1-2 technicians	100,000
Equipment	50,000
<i>Electronics, safing arming, fuzing and firing Subtotal</i>	<i>150,000</i>
<u>Facilities</u>	
150 acre ranch	150,000
Improvements and Maintenance	50,000
<i>Facilities Subtotal</i>	<i>200,000</i>
<i>Transportation and delivery</i>	<i>3,000</i>
<i>Procurement & Travel</i>	<i>150,000</i>
Total	1,433,000

Acquiring Fissile Material

Based on the foregoing analysis, summarized in the above table, a terrorist organization like al Qaeda could plausibly build and deliver a nuclear weapon for less than \$2 million. This estimate leaves substantial room in a notional budget of ten million dollars for the cost of acquiring highly enriched uranium.

Estimating the cost of acquiring fissile material is quite difficult. A terrorist group probably would not be able to produce significant amount of fissile material, despite the apparent interest of Aum Shinrikyo.⁷ A terrorist group would be more likely to either purchase the HEU on the black market or attempt to steal the material from a poorly guarded facility. Intelligence reports suggest terrorist groups have engaged in activities in Russia that are consistent with looking for opportunities to acquire fissile material.⁸

⁷ Bunn and Wier, *Securing the Bomb: An Agenda for Action*, 2004, p 18.

⁸ The National Intelligence Council reports that “Russian authorities twice thwarted terrorist efforts to reconnoiter nuclear weapon storage sites ...” *Annual Report to Congress on the Safety and Security of Russian Nuclear Facilities and Military Forces*, National Intelligence Council, December 2004. Available at: http://www.dni.gov/nic/special_russiannuke04.html

The “market” for black market fissile material is an unusual one. The market itself is “as a whole is populated by amateur criminals, scam artists, and (on the demand side) undercover police and police decoys.”⁹ Moreover, with so few sellers and buyers, the price is likely to reflect the negotiating power of the two parties.

Only one documented case exists of smugglers having obtained highly enriched uranium. In 1994, Prague police arrested members of a smuggling ring involving Czech, Slovak and Russian nationals who had acquired 10 kilograms of HEU (and indicated the ability to supply up to 40 kilograms in a short period). The Prague case indicates the difficulty in estimating a market price – while the Russian suppliers were asking \$800/gram, the middlemen doubled the price to \$1600-\$1800.¹⁰ At those prices, terrorists would need to spend several tens of millions of dollars to acquire enough fissile material.

The most interesting work in thinking about smuggling of black market nuclear materials involves “demand-driven” markets where the price of the fissile material results from a smuggling operation initiated by the procurer of the fissile material.¹¹ Given a demand-driven model, we might expect to see significantly lower prices than in supplier-initiated cases like Prague, where police spend little effort haggling with criminals.

The Khartoum case, in which al Qaeda agents paid \$1.5 million for a 2-3 foot cylinder containing what they believed to be highly enriched uranium, is an interesting data point.¹² The mass of the cylinder is not known, nor can one intuit whether bin Laden believed further purchases would be necessary. Compared to the estimated tens of millions of dollars involved in the Prague case, a price of a few million dollars is more plausible for a demand-driven transaction in which the buyer negotiates the cost up front. Absent confirmation of the cylinder’s mass, one may assume a terrorist group might need to make two or three such purchases for a range of \$3-5 million, with \$4 million dollars as a working average.¹³

⁹Rensselaer Lee, “Nuclear Smuggling: Patterns and Responses,” *Parameters*, (Spring 200) p.101.

¹⁰ “Appendix B,” *Staff Statement U.S. Permanent Subcommittee on Investigations (Minority Staff) Hearings on Global Proliferation of Weapons of Mass Destruction: Illicit Trafficking in Nuclear Materials*, March 22, 1996, pp.1-3 in *Global Proliferation of Weapons of Mass Destruction*, “Hearings before the Permanent Subcommittee on Investigations of the Senate Committee on Governmental Affairs, S. Hrg. 104-422, Part II (March 13, 20, and 22, 1996) pp.393-395

¹¹ Lee, “Nuclear Smuggling ...” p.102-104.

¹² United States District Court, Southern District of New York, *United States v. Usama bin Laden et al.*, defendants. Testimony of prosecution witness Jamal Ahmad Al-Fadl. See the transcript for Day 2 (7 February 2001) pp 257-366.

¹³ This is approximately the market price of HEU. Oak Ridge National Laboratory in the United States sells 99% U-235 (far more highly enriched than necessary) at a cost of \$57/milligram. E-mail to Peter D. Zimmerman from Ms. B. A. Benton, Oak Ridge National Laboratory, 29 March 2006. The Oak Ridge cost for super-grade material suggests, at least to an order of magnitude, the direct cost to a state such as North Korea or Iran, should it elect to transfer materials to a non-state actor.

With design and fabrication expenses running less than 2 million dollars, two things become clear. First, the majority of cost, and by extension difficulty, associated with a clandestine effort to build a crude nuclear device is likely to be associated with acquiring nuclear explosive material. By implication, the additional cost of designing a relatively more reliable weapon is trivial. A job worth doing, it would seem, is worth doing well.

Second, given our initial budget of \$10 million, a well-financed terrorist organization need not worry unduly about scams or buying bogus NEM. The failed al Qaeda effort to purchase HEU from Sudan cost just \$1.5 million. Falling victim to such a scam would not threaten the cost effectiveness of developing a nuclear weapon. Poor quality or fake NEM may simply be an acceptable cost of doing business, provided the details of attempt to purchase nuclear material does not reveal the existence of the plot.

If It Is So Easy, Why Hasn't It Happened Yet?

Our scenario does not suggest that terrorists would find building a nuclear weapon either easy or inexpensive. Such a group would find, however, that nuclear terrorism appears to be cost effective at the margin. Although building a nuclear device remains an expensive, complex undertaking out of reach for most organizations, a well financed organization that seeks to kill very large numbers of people may well find nuclear terrorism an irresistible option.¹⁴

The most important obstacle remains the difficulty in acquiring a sufficient amount of nuclear explosive material. To date, most instances of smuggling of nuclear materials have involved quantities and grades of NEM that are simply insufficient for building a weapon. A second reason is that only a very small number of terrorist groups fit the profile we have outlined here: interested in mass casualties, well financed and organizationally sophisticated. We have identified only two groups in recent history with all three qualities: al Qaeda and Aum Shinrikyo.¹⁵

Both Aum Shinrikyo and al Qaeda were constrained principally by the lack of available nuclear explosive material. Both groups faced other constraints, as well. Al Qaeda lacked the necessary technical expertise, as evidenced by the decision to pay \$1.5 million for metal that operatives falsely concluded was uranium and crude drawings in documents found in Afghanistan. In the months before September 11, 2001, al Qaeda took steps to remedy this deficiency. Bin Laden received two former Pakistani nuclear officials in August of 2001, asking them to help recruit other Pakistani experts with expertise in building nuclear weapons.¹⁶ Bin Laden has yet to find his Oppenheimer.

¹⁴ Bunn and Wier, *Securing the Bomb: An Agenda for Action*, 2004, p 27.

¹⁵ Daly, Sara, John Parachini, and William Rosenau, "Aum Shinrikyo, Al Qaeda, and the Kinshasa Reactor: Implication of Three Case Studies for Combating Nuclear Terrorism," RAND Corporation (2005).

¹⁶ The details of the "Kandahar Campfire meeting" are recounted in Ron Suskind, *The One Percent Doctrine: Deep Inside America's Pursuit of its Enemies Since 9/11*, New York, NY: Simon and Schuster, 2006, pp.26-28.

Aum Shinrikyo appears to have been slowed by a combination of limited technical expertise and ideological considerations that imposed an accelerated timetable for an attack using Sarin. Aum's bizarre purchase of a ranch in Australia to prospect for uranium would be laughable if the intent behind the action were not so appalling. Aum actively recruited several hundred scientists – although apparently no nuclear physicists. Aum has apparently made contact with Russian nuclear scientists, including an Aum member who worked for the Kurchatov Institute in Moscow,¹⁷ and actively recruited several hundred scientists although apparently no nuclear physicists were among them.

What Should We Do?

The most useful act is to prevent the acquisition by the terrorists of nuclear explosive material of such purity and in such quantity as to permit the construction of a bomb. There is no substitute for fissile material. However, if the attempt to control fissile material should fail, the defense must (and can) have other options available.

In principle, all states with highly enriched uranium (or plutonium) should exercise tight control over their material.¹⁸ In practice, this may well prove impossible, and is certainly impossible to prove because the amount of HEU and plutonium made, world wide, is not well known.¹⁹ Whereas one can imagine “Fort Knox” style protection, the fact remains that fissile material, including NEM, is an item of commerce, and is moved from place to place – sometimes with common carriers.²⁰ Opportunities for direct theft and bribing of the nuclear custodians abound. Therefore, significant effort must be put into theft prevention, theft detection, and personnel reliability programs. The disappearance of a reasonable fraction of a critical mass of NEM may well be the first tip-off to a nuclear plot.

¹⁷ A RAND report notes, among other suspicious contacts in Russia, “Aum targeted Russia’s premier nuclear research facility, the Kurchatov Institute, for expertise and technology because it reportedly possessed hundreds of kilograms of weapons-usable uranium.” Sara Daly, John Parachini, William Rosenau, *Aum Shinrikyo, Al Qaeda, and the Kinshasa Reactor: Implications of Three Case Studies for Combating Nuclear Terrorism*, Santa Monica, CA: RAND, 2005, pp.13-16. Available at: http://www.rand.org/pubs/documented_briefings/2005/RAND_DB458.pdf. A Senate Government Affairs staff investigation was “able to confirm, through a visit to the Kurchatov Institute, that an employee of the Institute was, and still is, a member of the Aum” as of 1995. *Global Proliferation of Weapons of Mass Destruction: A Case Study on the Aum Shinrikyo*, Senate Government Affairs Permanent Subcommittee on Investigations, October 31, 1995. Available at: http://www.fas.org/irp/congress/1995_rpt/aum/index.html.

¹⁸ See: Graham Allison, *Nuclear Terrorism: The Ultimate Preventable Catastrophe*, New York, NY: Henry Holt & Company, August 2004 and Matthew Bunn and Anthony Wier, *Securing the Bomb 2006: The New Global Imperatives*. Washington, D.C.: Project on Managing the Atom, Harvard University and Nuclear Threat Initiative, July 2006.

¹⁹ For example, a 1996 DOE historical report documenting the first fifty years of plutonium production in the United States revealed a discrepancy of more than 600 kg in the plutonium inventories in waste generated at Los Alamos. Arjun Makhijani and Brice Smith, *Dangerous Discrepancies: Missing Plutonium in Los Alamos National Laboratory Waste Accounts*, Institute for Energy and Environmental Research, April 21, 2006..

²⁰ Anna M. Pluta and Peter D. Zimmerman, *Nuclear Terrorism: A Disheartening Dissent*, Survival, vol. 48, no. 2, Summer 2006, p 55-70.

Second, the United States should focus on possible sources of foreign expertise. Most terrorist groups screen for “quality” among terrorist operatives.²¹ Both al Qaeda and Aum Shinrikyo actively attempted to recruit technically trained members. Sustaining current programs to employ former weapons scientists, and perhaps expanding those programs to include scientists from places like Pakistan or Iraq, is critical. The intelligence community should, to the extent possible, profile the technical and scientific capabilities of terrorist organizations and identify specific individuals who might be involved in nuclear terror plot. These individuals and their families could then be targeted for programs that provide alternative employment or otherwise discourage continued association with terrorist groups.

The budget for a nuclear terror plot is feasible within the known resources of al Qaeda and Aum Shinrikyo at their high points. Indeed, the cost is on the order of \$100 per murder. Neither personnel nor facilities costs drive the expense; the principal contribution is from the clandestine acquisition of nuclear explosive material, highly enriched uranium in this specific case.

Organizational problems in building a nuclear weapon are more severe than for an attack similar to the destruction of the World Trade Center and part of the Pentagon on 11 September 2001. However, it is unlikely that they exceed the effort needed to stage a series of mass death attacks capable of killing several tens of thousands of people. A wealthy organization wanting to kill several hundred thousand people could hardly find a more economical method than the construction and detonation of a small nuclear device. For that reason alone it is imperative to consider the nuclear threat as a serious one²² and not to suggest that because terrorism using a nuclear weapon has not yet happened, it is unlikely to happen in the future.²³

²¹ Ethan Bueno de Mesquita, “The Quality of Terror,” *American Journal of Political Science*, vol. 49, no. 3 (2005) pp.515-530.

²² Pluta and Zimmerman, *op. cit.*, p. 66

²³ Frost, *op. cit.*

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