Setting Priorities: Assessing the Global Risk of Nuclear Theft

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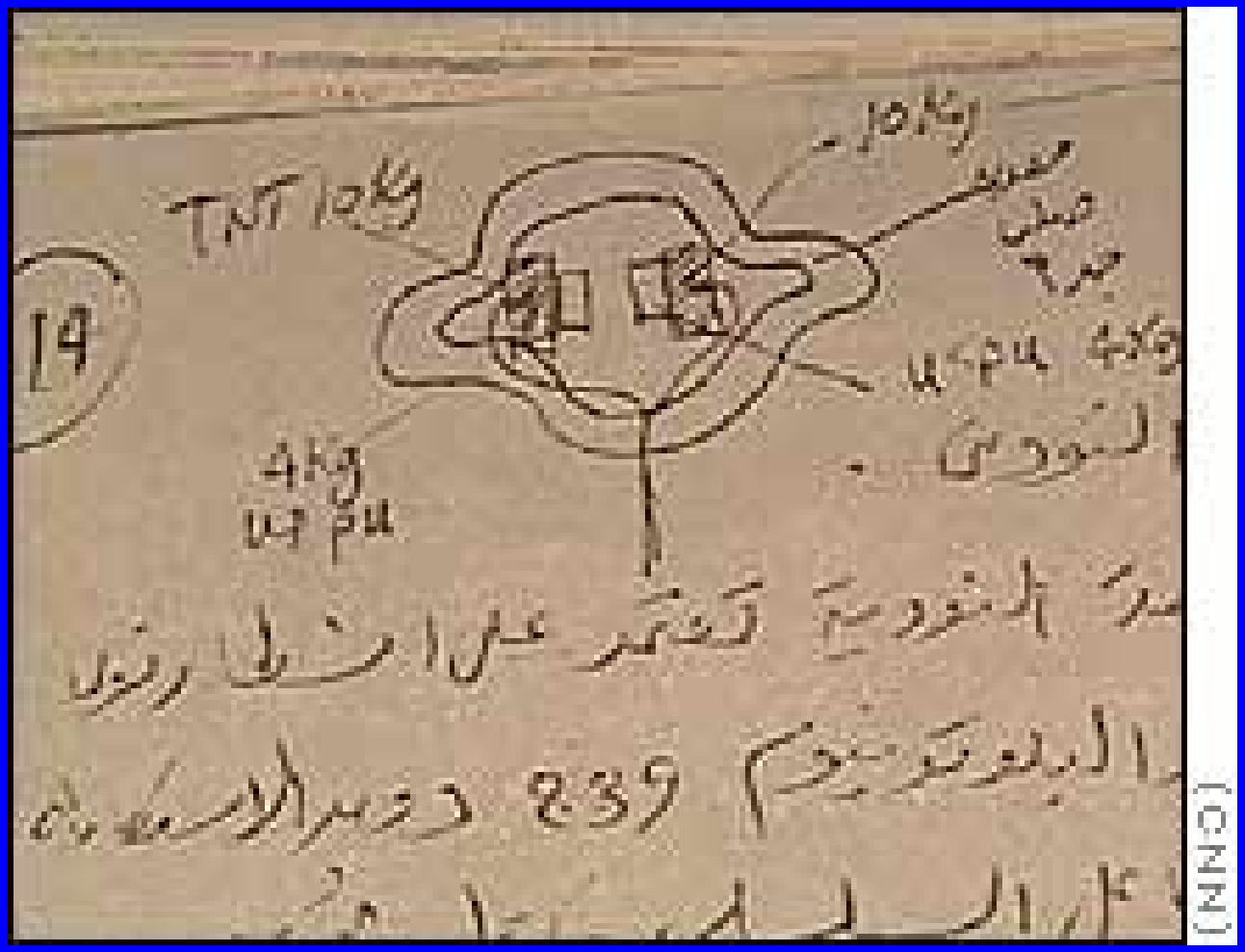
The nuclear terrorism threat is real

- CIA has documented “very professional” al Qaeda effort to get materials and expertise for a nuclear bomb dating back more than a decade
- Multiple documented cases of al Qaeda attempts to purchase stolen nuclear bomb materials, recruit nuclear expertise
- Japanese terror cult Aum Shinrikyo also attempted to acquire nuclear weapons
- Confirmed cases of Chechen reconnaissance at secret nuclear warhead storage sites
- Also multiple confirmed instances of al Qaeda consideration of plans to sabotage reactors

Probability of catastrophic release may be higher from malevolence than from pure accident

Al Qaeda nuclear bomb sketch

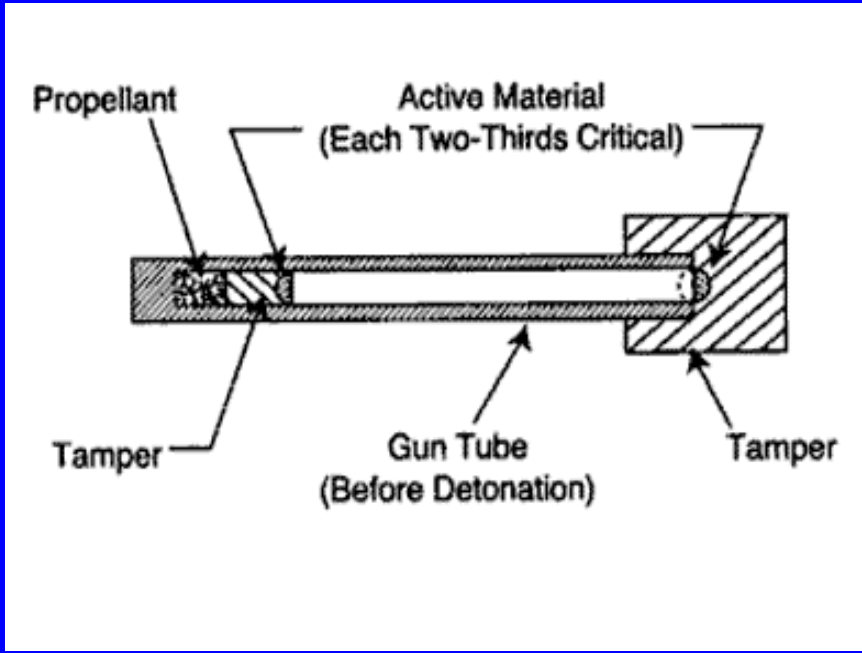


Source: CNN

With nuclear material, terrorists may be able to make crude nuclear bombs

- With HEU, gun-type bomb – as obliterated Hiroshima – very plausibly within capabilities of sophisticated terrorist group
- Implosion bomb (required for Pu) more difficult, still conceivable (especially if they got help)

Internationally, widespread skepticism that this risk is significant

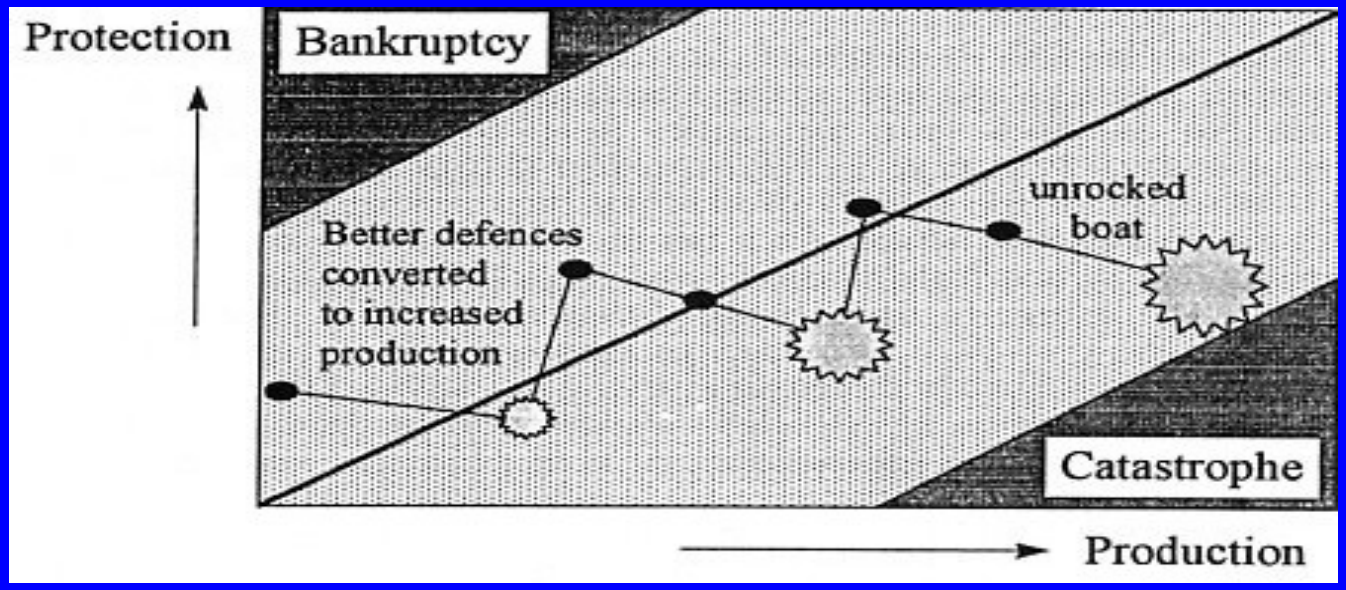


Source: NATO

Nuclear terrorism risks: the good news

- No convincing evidence that a nuclear weapon or the materials to make one have yet fallen into the hands of a terrorist group or hostile state
- No convincing evidence any terrorist group has yet put together the expertise to make a bomb if it got the material
  - Some evidence of confusion, lack of nuclear knowledge by some in al Qaeda
- Failed Aum Shinrikyo and al Qaeda efforts suggest that even sophisticated, well-financed terrorist groups have difficulty pursuing the nuclear path
- Major post-9/11 disruption of old centrally controlled al Qaeda has probably reduced their nuclear potential
- *But what may be happening that we don't know about?*

Risk management: avoiding both complacency and bankruptcy



Source: *James Reason,,* Managing the Risks of Organizational Accidents *(Ashgate, 1997)*

- Imaginary organization starts with protection emphasis
- Complacency leads to increasing shift toward production emphasis until incident occurs
- Long period with no incidents can lead to catastrophe – unless means put into place to counter complacency

Methodology for identifying the highest-risk nuclear facilities or transport legs

- Each stock's contribution to the global probability of terrorists getting a nuclear bomb:

$$R = P_{attempt} P_{success} P_{bomb\text{-}making}$$

- Where:
  - $P_{attempt}$ is the probability of a theft attempt at that site
  - $P_{success}$ is the probability the attempt would be successful
  - $P_{bomb\text{-}making}$ is the probability that adversaries would succeed in making a usable bomb from the stolen items
- $P_{success}$ is determined mainly by balance between security measures and adversary capabilities they must protect against
- $P_{bomb\text{-}making}$ is determined by the quantity and quality of the material
- $P_{attempt}$ is presumably determined by the other two variables

Key risk variables

- Most important variables are:
  - Distribution of adversary capabilities (varies significantly by country)
  - Adversary capabilities security system can defeat
    - » Determined not only be security system, but by facility environment (for example, hands-on bulk-processing facility may find covert insider thefts more difficult to prevent than facility with rarely-accessed material stored in a vault)

$$R_a = P_{at} P_{s(at)} P_w$$

  - Quantity and quality of nuclear material available to steal
- Difference from standard DOE "risk equation"
  - Not a single DBT – takes into account that threat may be different in different countries and regions
  - Does not take probability of attempt as 100%

Plausible adversary capabilities vary in different countries: some indicators

Threat Indicators for Selected Countries

Country	Terror Index (10-100)[a]	Security Risk (1-5)[b]	Corruption (1-10)[c]	GDP/capita, PPP (2004)[d]
Russia	77.5	3.75	7.6	$ 9,097.83
Pakistan	77.5	4.25	7.9	$ 2,044.99
United States	66.25	3	2.4	$ 36,465.05
Japan	45	1.5	2.7	$ 26,883.71
Canada	33.75	1	1.6	$ 28,732.64
Uzbekistan	51.25	3.75	7.7	$ 1,718.30
Unnamed Country	43.75	3.25	5.5	$ 10,471.59

[a]World Markets Research Centre, *WMRC Global Terrorism Index 2003-2004* (London: WMRC, 2003), modified as described in the notes.
[b]World Markets Research Centre, on-line *Country Risk Reports* (London: WMRC, 2003-2004).
[c]Transparency International, *Corruption Perceptions Index 2004* (Berlin: TI, 2004), inverted as described in the notes.
[d]World Bank, *World Development Indicators: 2006* (Washington, D.C.: World Bank, 2006), 2004 incomes in constant 2000 dollars.

Adversary capabilities may be substantial: demonstrated outsider threats

- Large overt attack
  - e.g., Moscow theater, October 2002: ~ 40 well-trained, suicidal terrorists, automatic weapons, RPGs, explosives, no warning
- Multiple coordinated teams
  - e.g., 9/11/01 -- 4 teams, 4-5 participants each, well-trained, suicidal, from group with access to heavy weapons and explosives, >1 year intelligence collection and planning, striking without warning
- Significant covert attack
  - e.g., multiple incidents of tunneling into bank vaults
- Use of unusual vehicles
  - e.g., helicopters used in many recent jail escapes
  - e.g., speedboat planned for use in $200M Millennium Dome theft

Adversary capabilities may be substantial: demonstrated insider threats

- Multiple insiders working together
- Often including guards
  - Most documented thefts of valuable items from guarded facilities involve insiders – guards among the most common insiders
  - Goloskokov: guards “the most dangerous internal adversaries”
- Motivations:
  - Desperation
  - Greed/bribery
  - Ideological persuasion
  - Blackmail

A trustworthy employee may not be trustworthy anymore if his family’s lives are at risk

Nuclear security varies widely worldwide

- No specific and binding global standards for nuclear security in place:
  - Physical Protection Convention amendment useful, but does not specify what levels of security are needed
  - Nuclear Terrorism Convention also useful but sets no standards
  - UNSC 1540 requires all states to provide “appropriate effective” security for any nuclear stockpiles they have – no definition of what the essential elements of an “appropriate effective” system are
  - IAEA recommendations (INFCIRC/225 Rev. 4) are more detailed, but still not very specific, and not binding (e.g., Cat. I material should have a fence with intrusion detectors, and guards – but how many guards, how strong a fence, how good intrusion detectors, able to defeat what?)
- Stanford survey: some respondents did not have required protections against insiders, some did not include sabotage

Widely varying nuclear security (II): Moscow HEU building, 1994

Source: DOE

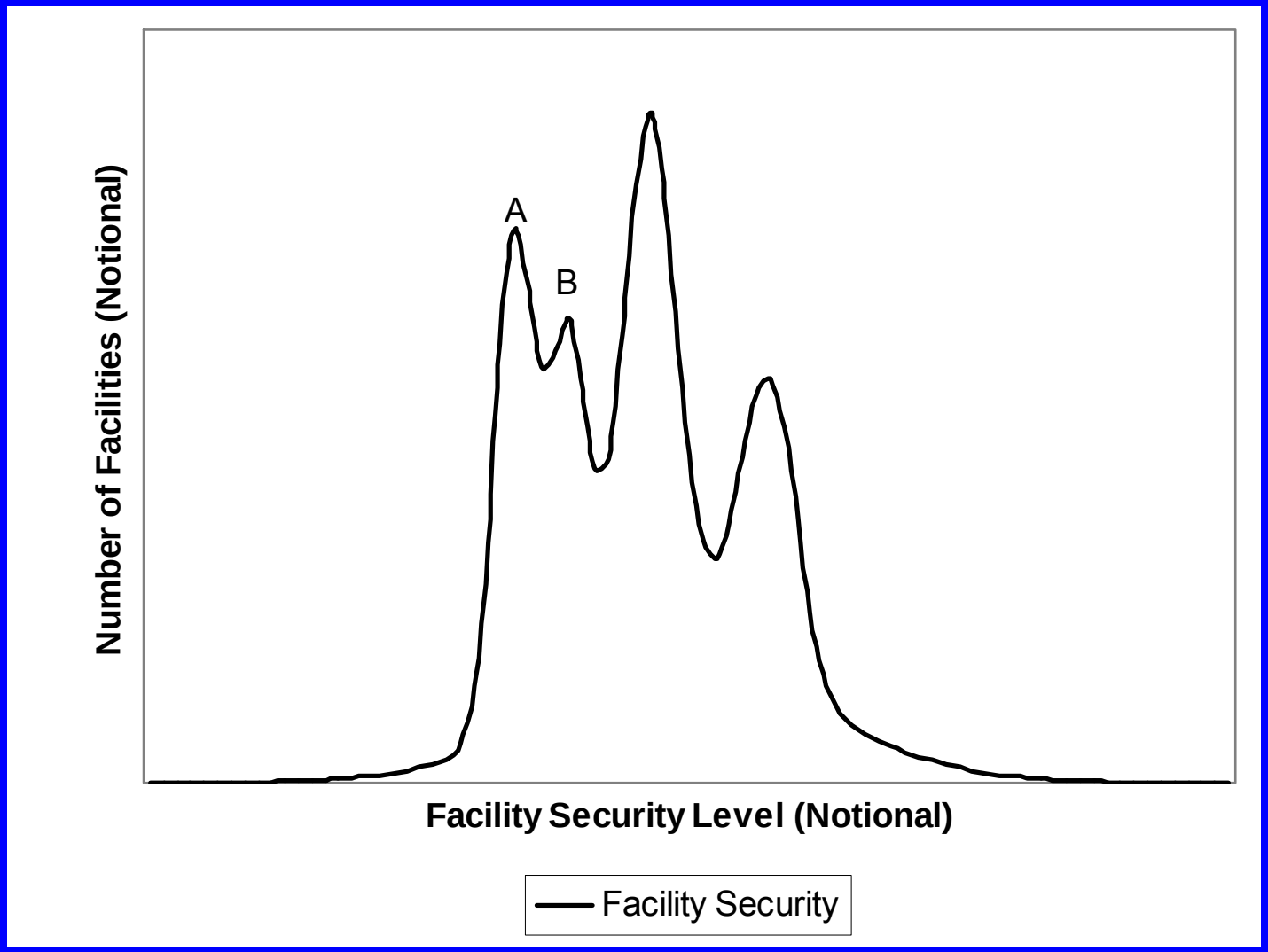
Widely varying nuclear security (III): The threat in Russia today

- Russia is a different place today than 10 years ago – economy has stabilized; government in firmer control; nuclear workers paid a living wage, on time
- Nuclear security at most facilities dramatically improved – 1990s incidents of one insider or outsider stealing without detection would generally not be possible now
- But:
  - Resources devoted to nuclear security remain far below what is needed
  - "Security culture" issues – e.g., guards patrolling without ammo
  - Massive corruption, sophisticated insider theft conspiracies
  - Huge terrorist attacks (30-100 heavily armed attackers)
  - Confirmed terrorist reconnaissance on nuclear warhead sites
  - Businessman offering $750,000 for stolen plutonium

Widely varying nuclear security (IV): A global issue

- > 40 countries with weapons-usable material – few with security measures that can provide high probability of defeating all demonstrated terrorist and criminal threats
- Pakistan: small stockpile, heavily guarded – but huge threats (insiders, outsiders)
- HEU-fueled research reactors – some have enough HEU for a bomb on-site, usually very modest security measures (in some cases, night watchman and chain-link fence)
- Transport of nuclear material especially difficult to protect, carried out under wide range of security levels

Judging the chance of successful theft: focusing on the tails of distributions



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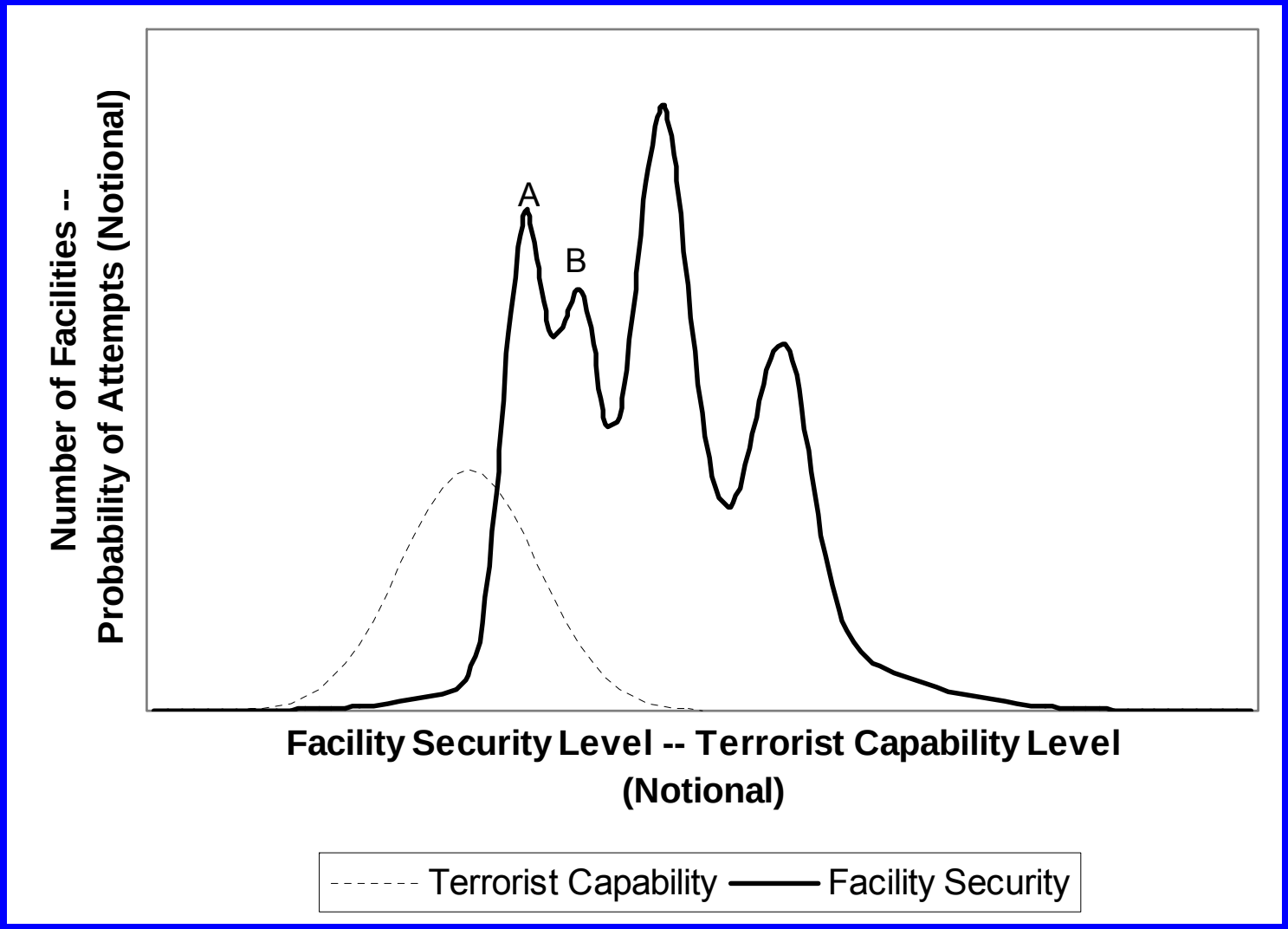

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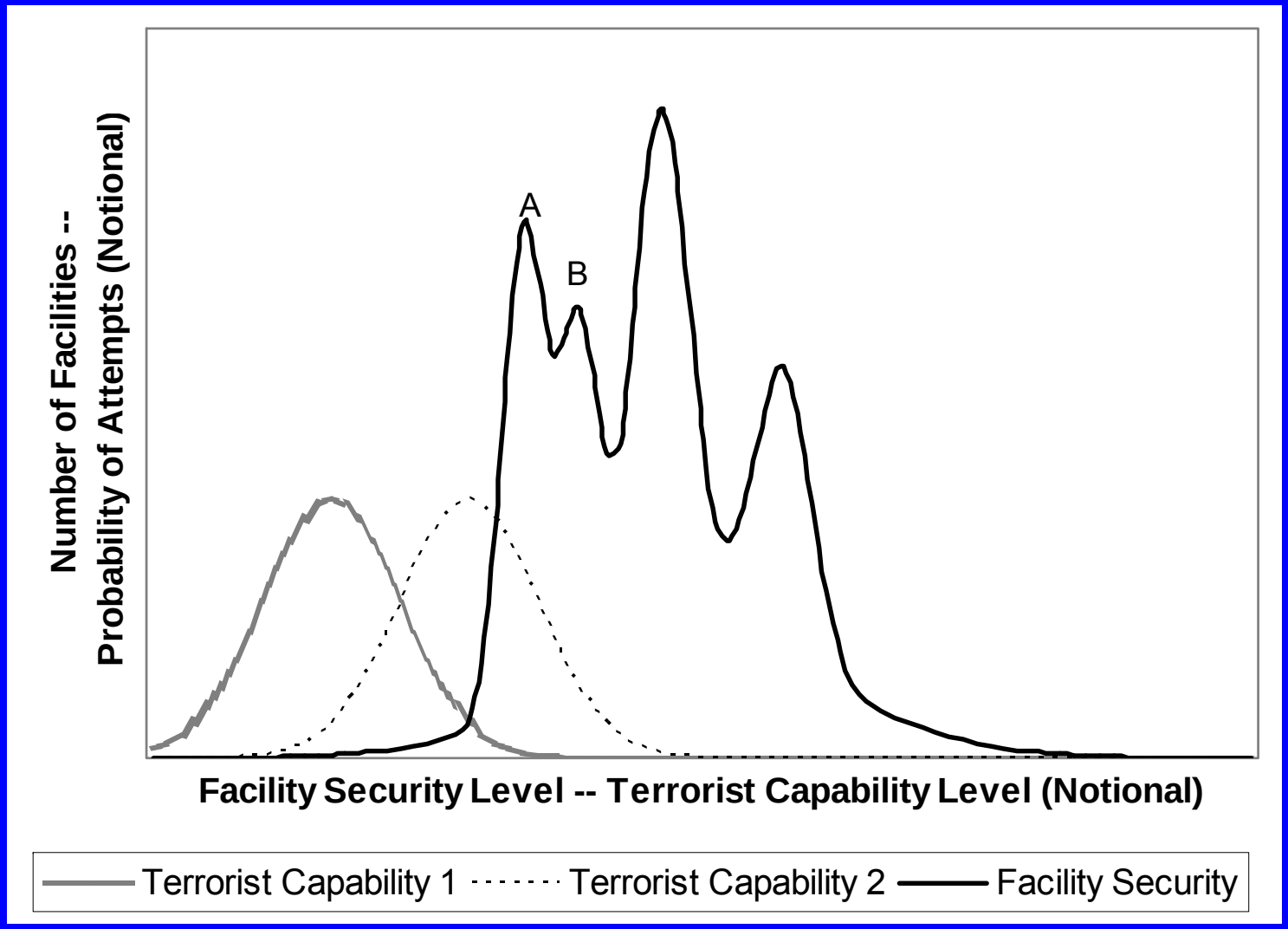

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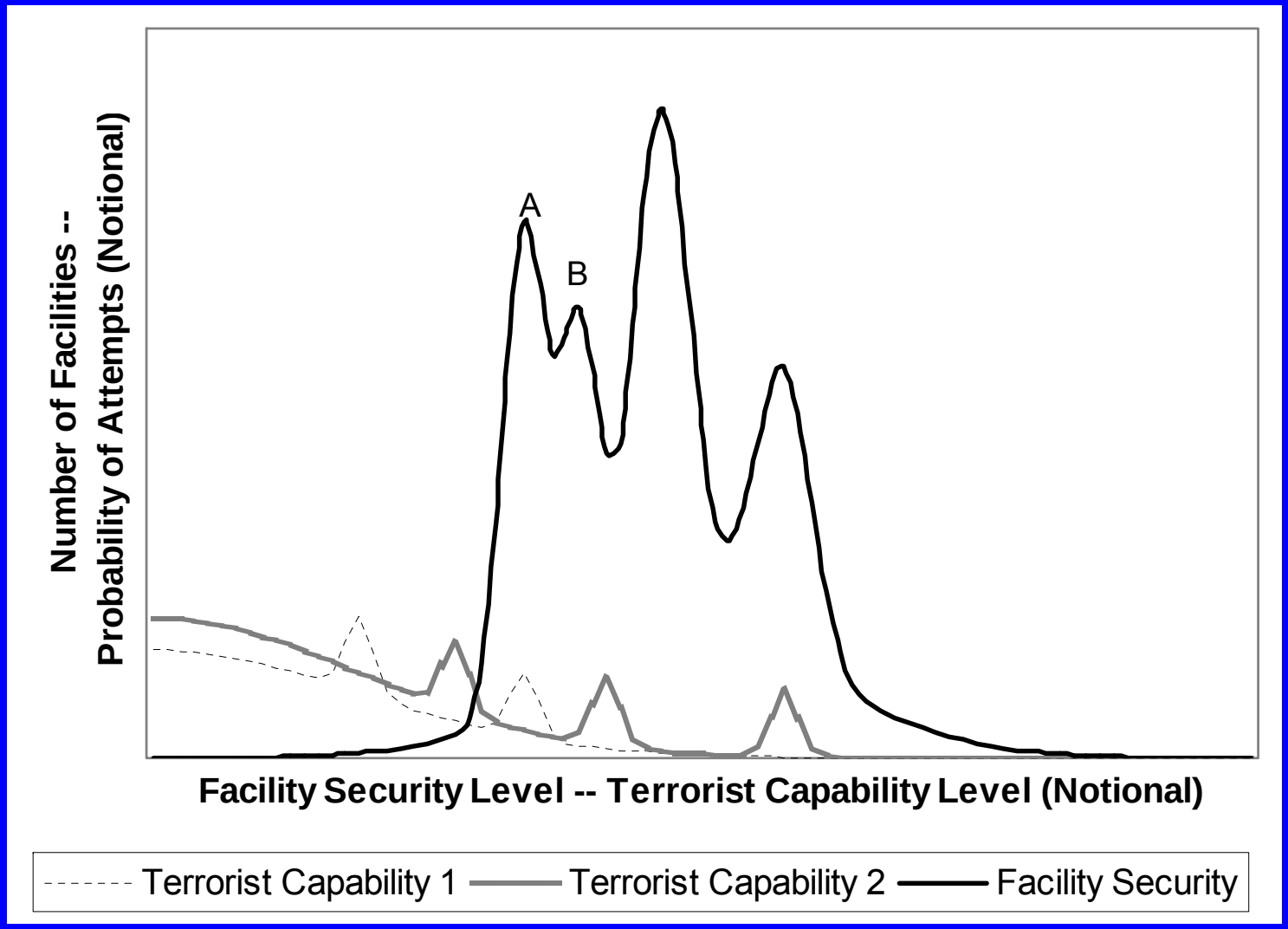
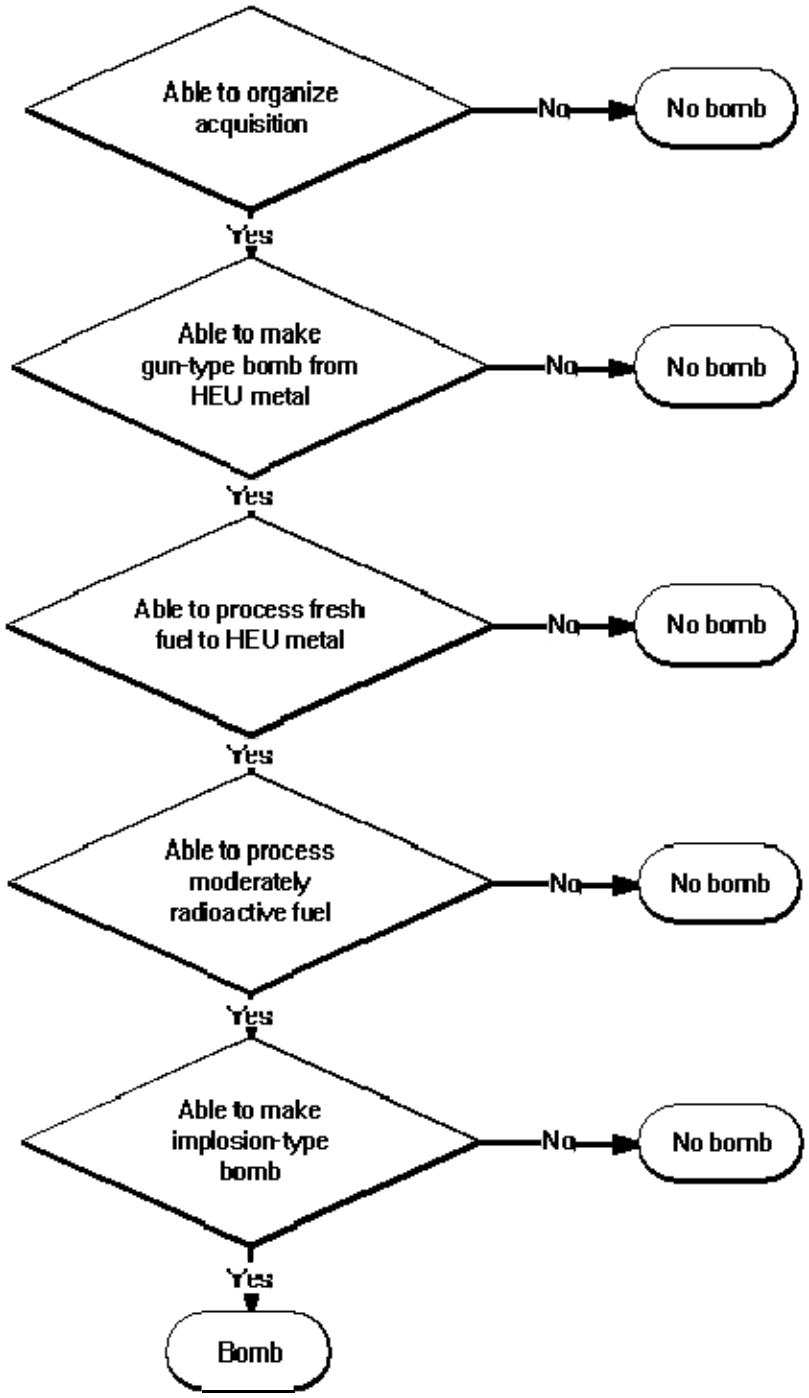


Material quantity and quality

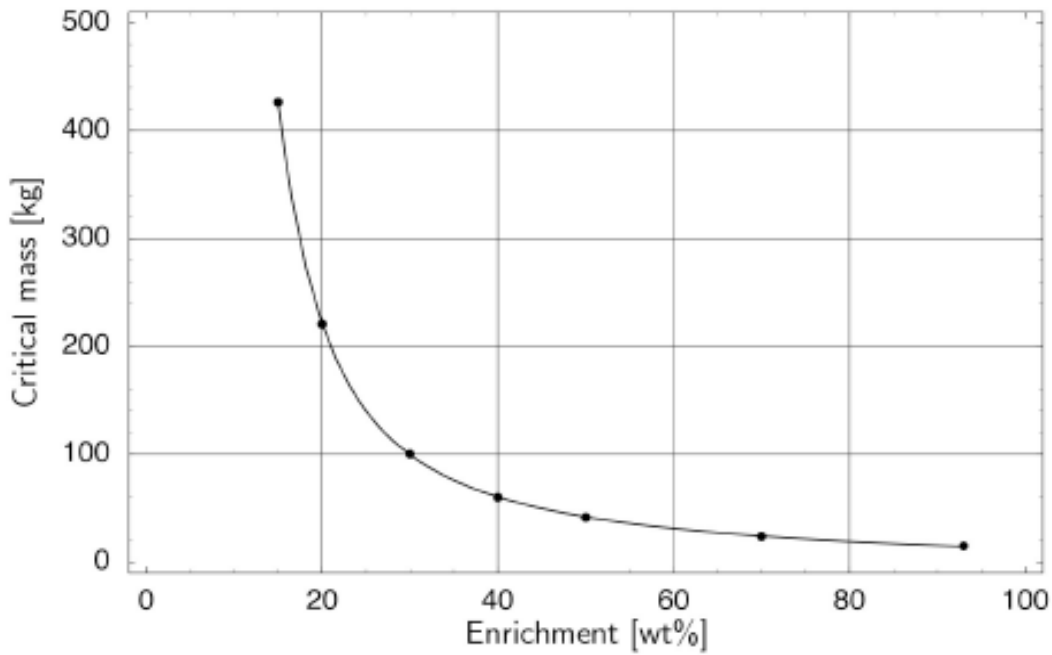
- Gun-type vs. implosion-type bombs
  - Estimate: Prob. of adversary success in making implosion-type roughly 60% that of gun-type (*for those adversaries able to make a gun-type*)
- Quantity: risk increases rapidly as quantity reaches amounts needed for a terrorist bomb, much more slowly thereafter
- Isotopic barriers: critical mass, pre-detonation, heat, reduced yield
- Chemical barriers: need for separation, processing
- Radiological barriers: doses during theft, processing, difficulty of processing with remote handling, risk of detection
- Size and mass barriers

Categorization should avoid "cliffed safeguards" where protection dramatically reduced past some arbitrary threshold

Example: capabilities needed to make a bomb from 20 kg of HEU in irradiated research reactor fuel



Isotopics: Uranium and critical mass



Critical mass of a uranium sphere with a 10 centimeter thick beryllium reflector. MCNP 4B calculations at 300 degrees K. Assumed uranium density 19 g/cm^3.

Source: Alexander Glaser, "On the Proliferation Potential of Uranium Fuel for Research Reactors at Various Enrichment Levels," *Science and Global Security* 14, 2006, pp. 1-24.

*Should use "effective kilograms" (kgHEU*fU235^2) rather than kg U235 to assess quantity – provides better estimate of risk*

Isotopics: plutonium

Key Properties of Different Grades of Plutonium

Grade	Critical Mass (kg)	Neutrons /g-sec	Heat (W/kg)
Super-grade	n.a.	18	2.0
Weapon-grade	11.5	53	2.5
Fuel-grade	13.2	202	14.1
Reactor-grade (33 GWd/t)	14.6	338	14.4
Reactor-grade (50 GWd/t)	n.a.	457	25.1
MOX-grade	n.a.	471	22.2
FBR blanket	n.a.	36	2.1

Source: Neutron and heat generation are calculated from the isotopic properties and the contents of the different grades presented in the text. Critical masses are for bare spheres of alpha-phase plutonium with a density of 19 g/cc, presented in Alexander Glaser, "On the Proliferation Potential of Uranium Fuel for Research Reactors at Various Enrichment Levels," *Science and Global Security* 14, 2006, pp. 1-24.

Reactor-grade plutonium is weapons-usable

- "Virtually any combination of plutonium isotopes -- the different forms of an element having different numbers of neutrons in their nuclei -- can be used to make a nuclear weapon... At the lowest level of sophistication, a potential proliferating state or subnational group using designs and technologies no more sophisticated than those used in first-generation nuclear weapons could build a nuclear weapon from reactor-grade plutonium that would have an assured, reliable yield of one or a few kilotons (and a probable yield significantly higher than that). At the other end of the spectrum, advanced nuclear weapon states such as the United States and Russia, using modern designs, could produce weapons from reactor-grade plutonium having reliable explosive yields, weight, and other characteristics generally comparable to those of weapons made from weapons-grade plutonium.... Proliferating states using designs of intermediate sophistication could produce weapons with assured yields substantially higher than the kiloton-range possible with a simple, first-generation nuclear device."
  - *Nonproliferation and Arms Control Assessment of Weapons-Usable Fissile Material Storage and Excess Plutonium Disposition Alternatives* (Washington, DC: DOE, January 1997)

Proposed categorization of nuclear materials: quality

Attractiveness Level	Material Type	Discount Factor
A: Weapons and Gun-Type Bomb Materials	Weapons, ≥50 eff. kg HEU metal (>40% enrichment)	1.0
B: Implosion-Type Bomb Materials	Pu metal, < 50 eff. kg HEU metal (>40% enrichment), HEU metal ≤ 40% enrichment	0.6
C: Compounds and Mixes Not Requiring Chemical Separation	Oxides, carbides, nitrates, other direct-use compounds, alloys and mixtures	0.8
D: Compounds and Mixes Requiring Chemical Separation	Alloys and mixes requiring chemical separation; fuel elements and assemblies; solutions	0.5
E: Lightly Irradiated Material	Emitting ~20-400 rad/hr at 1 m	0.8
F: Irradiated Material Requiring Remote Handling	Emitting ~400-10,000 rad/hr at 1 m	0.2
G: Highly Irradiated Material Imposing Disabling Doses During Theft	Emitting >10,000 rad/hr at 1 m.	0.001

Implementing the method: example risk assessments in a few countries

Country Risk Estimates With a Rating-Based Approach

Country	Threat Level	Sec. Level	Att. Prob.	Theft Prob.	Discount Factor	Risk Rating
Russia	4-5	3	0.45	0.55	1.0	0.25
Pakistan	5	3-4	0.5	0.55	1.0	0.27
United States	3	4-5	0.3	0.16	1.0	0.049
U.S. res. reactors	3	1-2	0.3	0.55	0.4	0.066
Japan	2	2-3	0.2	0.25	1.0	0.050
Canada	2	3	0.2	0.2	1.0	0.040
Uzbekistan	4-5	2-3	0.45	0.65	0.2	0.058
Unnamed Country	3-4	2	0.35	0.55	1.0	0.19

Source: Author's estimates

Reducing the risk

- Should use this or similar methodologies to focus on rapidly upgrading security or removing material from the highest-risk sites worldwide
- Need a global campaign, integrating many policy tools
  - Most important single ingredient: new steps to convince foreign leaders, nuclear managers, that nuclear terrorism is a real and urgent threat to *them*, deserving their time and resources
    - » Joint threat briefings, nuclear terrorism "war games," indepdent security-assessment teams, and more
    - » "Security Chernobyl" would have devastating political impact on nuclear industry – as with safety, worst security performers can be a problem even for the best performers
- President should appoint senior official to take full-time responsibility for leading, integrating the many efforts focused on reducing the risk of nuclear terrorism