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Evolving Opportunities for Nuclear Security Cooperation

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belfercenter.org/mta

Nuclear safety and security support nuclear energy growth

- Nuclear energy important to India's energy future (and those of other countries)
  - Clean, expandable non-intermittent power
- Public support requires public confidence that facilities will be safe and secure
- Fukushima accident had major effect on public, investor perceptions
  - Another major accident – or, worse, a terrorist attack – could doom prospects for nuclear growth on scale needed for major climate mitigation, pollution-reduction contribution
- Resources for safety and security are essential investments in the future of nuclear energy
- Safety and security are inextricably intertwined – often contribute to each other, sometimes conflict

Nuclear theft and sabotage are real dangers

- Multiple terrorist groups have sought nuclear weapons
  - al Qaeda's program progressed as far as carrying out explosive tests in the Afghan desert
  - Aum Shinrikyo had substantial effort before 1995 nerve gas attacks
  - Only hints of ISIS interest (extended monitoring of Belgian nuclear official) – but has more $, people, control of territory, ability to recruit globally than the others
- Multiple government studies (in U.S. and elsewhere) have concluded that sophisticated terrorist groups could make a crude bomb if they got the material
- ~20 cases of seizure of stolen nuclear bomb material in public record
- Also multiple cases of actual or planned nuclear sabotage
  - Most recent: Insider sabotage of Doel-4 turbine in 2014

A recent example: insider sabotage and a cleared terrorist at Doel-4

- August 2014: An insider at Doel-4 reactor in Belgium drains lubricant, destroys reactor turbine
  - >$100 million damage
  - Investigators unable to find culprit
  - Sabotage intended to cause economic damage, not radiation release
- Investigation finds that long before, contractor Ilyass Boughalab had access to vital area
  - Passed security clearance review in 2009
  - In late 2012, left to fight for terrorists in Syria (reportedly killed later)
  - Later convicted as part of "Jihad4Belgium" terrorist group

Source: Kristof Pieters

Existing Indian good nuclear security practices

- Nuclear operators required to protect against a range of both outsider and insider threats
- Centralized, professional security force for nuclear facilities
- Interagency process for regularly reviewing and adjusting threat levels/security postures (not done in U.S.)
- Plant-provided worker housing (not done in U.S.)
  - Increases chances that concerning behavior or outside recruitment attempts would be noticed
- Participation in international conventions and initiatives
  - Nuclear security summits
  - IAEA nuclear security programme (including India-led training)
  - Nuclear security conventions
  - INFCIRC/869, "Strengthening Nuclear Security Implementation"

Five especially key areas for nuclear security

- Like nuclear safety, nuclear security is never ”done” – requires focus on continuous improvement
- Effective nuclear security systems include many elements, face many challenges (as discussed at 2012 workshop)
- Effective approaches in five areas can greatly strengthen a country’s overall nuclear security program:

1. Design requirements covering the full spectrum of plausible adversary capabilities and tactics
2. Targeted programs to strengthen security culture
3. Comprehensive programs to protect against insider threats
4. Realistic performance testing and vulnerability assessment
5. Consolidating material to the minimum number of locations

Design requirements covering the full spectrum of plausible adversary capabilities + tactics

- Challenge: need to protect against plausible possibilities without wasting money on unrealistic threats
  - But adversaries learn, evolve, adapt
- IAEA recommendation: Physical protection systems must be "based on the State's current evaluation of the threat"
- Capabilities and tactics demonstrated in real incidents (nuclear and non-nuclear) include:
  - Attack by well-armed, well-equipped teams with military-style training and tactics (e.g., Västberga cash depot heist)
  - Deception and stealth (e.g., Antwerp Diamond Center heist)
  - Insider-outsider and insider-insider conspiracies (e.g., Pelindaba break-in)
  - Use of unusual vehicles (e.g., helicopters) or tunnelling to bypass security systems (e.g., multiple prison breaks and bank heists)

Programs to strengthen security culture

- Challenge: How to build organizational culture where people are always on the look-out for vulnerabilities to be fixed, ways to improve security?
  - "Good security is 20% equipment and 80% culture"
- IAEA recommendation: All organizations involved in physical protection should give due priority to security culture
- Every nuclear operating organization should have a targeted program in place to:
  - Assess its security culture
  - Strengthen security culture over time
- Some key elements:
  - Leadership focus on security
  - Broad understanding the threat – and security's importance
  - Structuring incentives to encourage staff to focus on security

Security culture matters: Propped-open security door

Source: U.S. Government Accountability Office

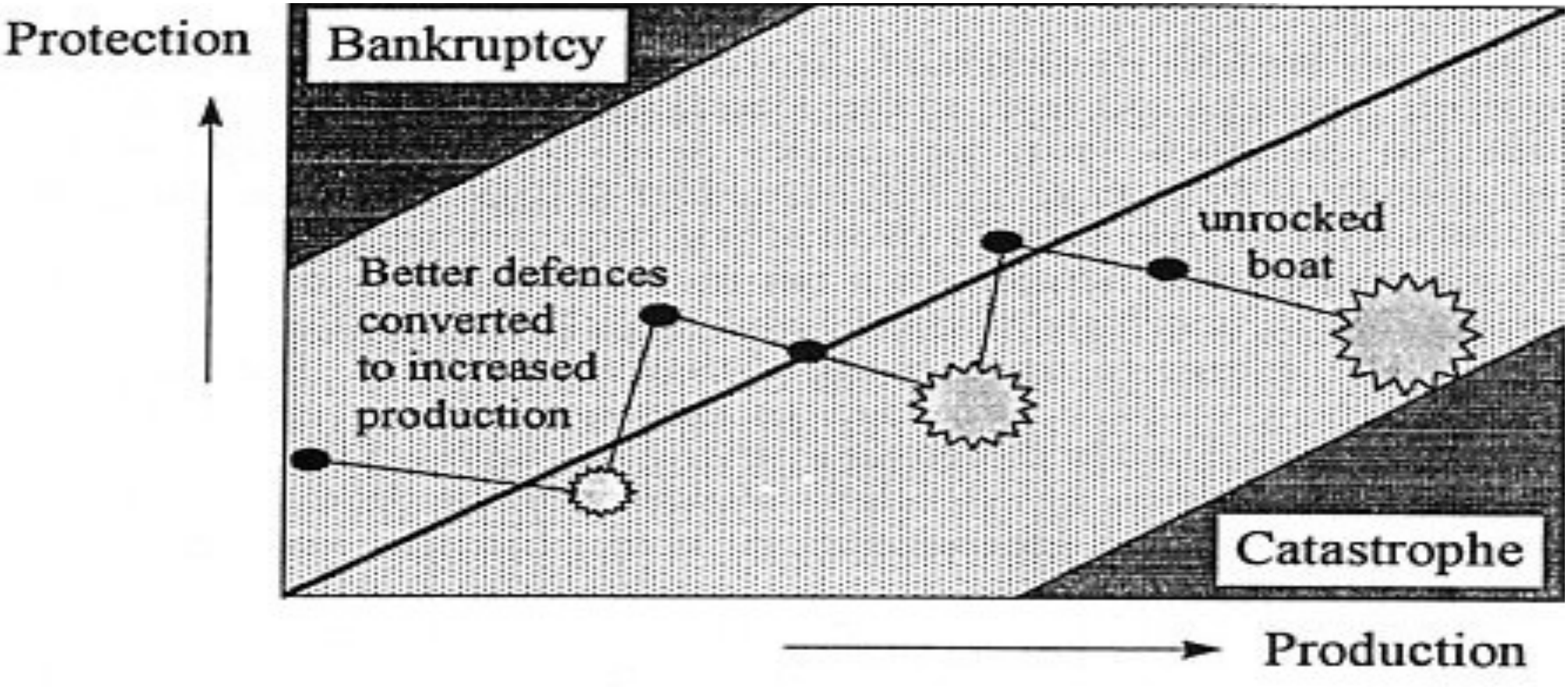
Y-12 intrusion, 2012: A failure driven by weak security culture

- July 2012: an 82-year-old nun and 2 other protesters in their 60s penetrate 4 layers of fences (3 alarmed), go right to building with 1000s of bombs worth of HEU, spend tens of minutes there before being accosted by 1 guard
- Multiple organizational failures rooted in weak security culture
  - Site attempted to install new detection system without spending needed resources. Result: 10x increase in false alarms
  - Security cameras had been broken for months – no one fixed
  - Guards had (apparently) gotten sick of constantly going to check false alarms – assumed all alarms were false alarms
  - Even heavily armed guards inside HEU facility didn't bother to check when they heard the protesters pounding
  - Guard who DID respond failed to follow procedures, left himself vulnerable if they had been real adversaries disguised as protesters

Complacency is the key enemy – but has deep roots

- Most nuclear facilities have never had a serious security issue (a real theft or sabotage attempt) in decades of operation
- Virtually no information is exchanged about the real incidents that *do* occur – no one hears about them
- 100% of the alarms in the average guard's career will either be false alarms or tests
- Existing security systems *look* impressive – easy to convince yourself they are impregnable
- Many sources of cognitive and organizational bias leading people to unduly discount low-probability, high-consequence events
  - No one gets promoted for making a $1/10^5$ risk into a $1/10^6$ risk
  - Every hour you spend on security is an hour *not* spent on something more likely to get you promoted

Success can lead to complacency



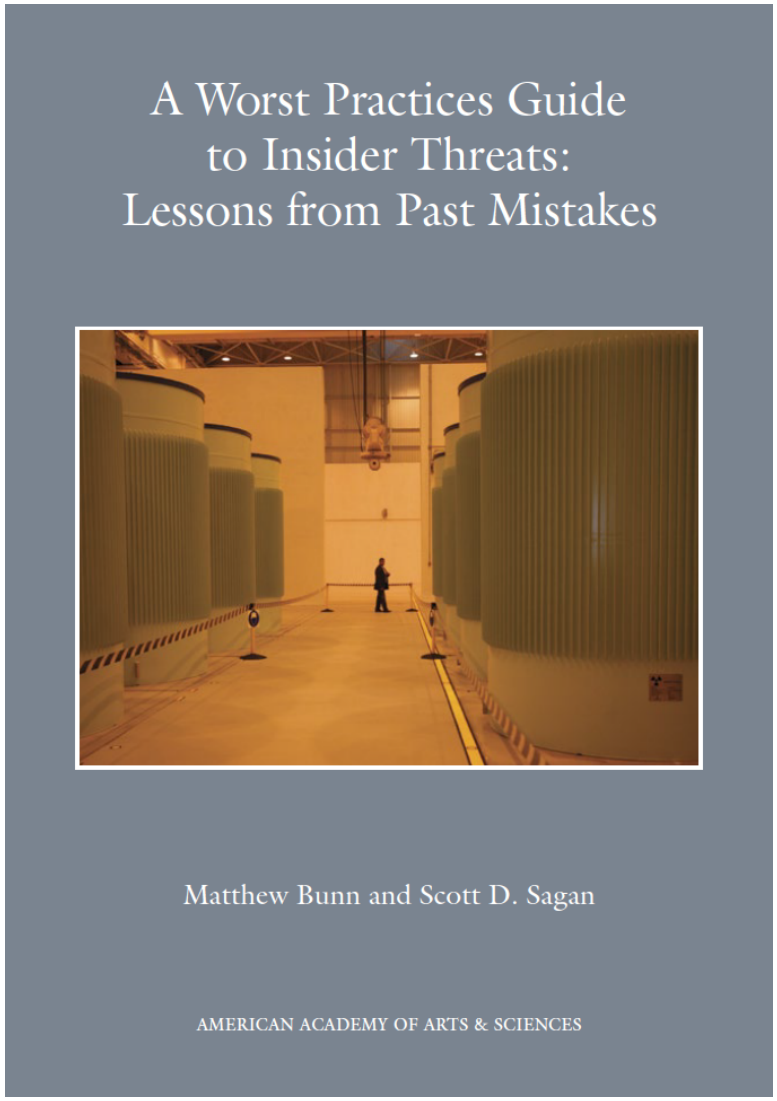
From James Reason, Managing the Risks of Organizational Accidents *(Ashgate, 1997)*

Comprehensive protection from insider threats

- Challenge: insiders are trusted by other staff, can use their specialized knowledge and authorized access to pose threat
  - Source of most past nuclear theft and sabotage cases
- IAEA recommendation: Design physical protection and material control and accounting to detect and deter insider adversaries
- Comprehensive insider threat program should include:
  - Background checks before access, and ongoing monitoring after access is granted
  - Material accounting and control sufficient to detect any theft, and identify when and where it happened (and who had access then)
  - Strong incentives for staff to report concerning behavior, potential vulnerabilities
  - Constant surveillance of material, vital areas for sabotage
  - Effective program to address employee disgruntlement

Insider threats are the most dangerous nuclear security problem

- People don't want to believe their friends and colleagues could betray the organization
  - Leads to serious lapses in protection against insider threats
- Getting people to report suspicious behavior is *very* difficult
- Often even obvious "red flags" go unreported, unaddressed
- Bunn-Sagan "Worst Practices Guide" on how *not* to handle the insider threat
- Forthcoming book with detailed case studies



Realistic performance testing and assessment

- Challenge: Many security systems that *look* effective can be beaten by intelligent and creative adversaries
  - Adversaries find vulnerabilities we didn't think of
- IAEA recommendation: Quality assurance to ensure protection system can protect against the design basis threat; force-on-force exercises at least annually
- Some key elements:
  - Create "red teams" with mission and incentives to find vulnerabilities and propose solutions
  - Conduct "tabletop" exercises and brainstorming workshops to identify and assess tactics adversaries might use
  - Conduct realistic tests of ability of intelligent adversaries (insiders and outsiders) to find ways to defeat the overall security system – including realistic force-on-force exercises
  - Address weaknesses identified

Consolidating material

- Challenge: Good security is expensive – and imperfect, so every site with HEU or plutonium still represents some risk
- Nuclear security summit commitment: minimize stocks and locations with HEU and plutonium
- Elements of an effective consolidation effort:
  - Convert HEU fuels to LEU where practible
  - Assess each location with nuclear weapons, HEU, or separated plutonium – do benefits still outweigh the risks? Could benefits still be achieved if material was removed and consolidated at another site?
  - Structure nuclear security regulations to give operators incentives to reduce costs by consolidating stocks of material

Principles all states with HEU, plutonium, or major nuclear facilities should implement

- Protect these items against the full spectrum of plausible adversary threats and capabilities
- Have well-trained, well-equipped on-site armed guard forces sufficient to defeat the threat
- Have comprehensive programs to protect against insider threats
- Have targeted programs to strengthen security culture, including regular security culture assessments
- Conduct in-depth assessments and realistic tests to ensure that nuclear security systems are meeting performance goals
- Have nuclear material accounting and control systems sufficient to detect thefts and localize them in place and time
- Provide effective cyber protection

Opportunities for nuclear security cooperation

- Broad range of U.S.-India nuclear security cooperation possible without compromising sovereignty, secrecy
  - Need not require visits to facilities
  - Can build on existing program of workshops at Global Centre
- India and the United States could establish expert groups in key technical areas, including those just identified:
  - Protecting against a full spectrum of plausible adversary threats
  - Strengthening security culture
  - Providing comprehensive protection against insider threats
  - Conducting realistic performance tests and vulnerability assessments
  - Consolidating nuclear material
- Working groups could develop projects for joint R&D, e.g.:
  - Improved vulnerability assessment tools
  - Improved material accounting and control

Opportunities for cooperation (II)

- Expanded regulator-to-regulator discussions
- Radiological source security
- Prevention and detection of illicit trafficking
- India is now committed to INFCIRC/869 – another potential focus for cooperation, e.g.:
  - Approaches to preparing for international peer reviews of nuclear security
  - Approaches to implementing key IAEA recommendations
- Joint development of initiatives to sustain nuclear security progress with the end of the summit process
  - Through IAEA
  - Through "Contact Group" of interested countries
  - Should the Global Initiative add a working group on nuclear security and physical protection?

Further Reading and Background Material

- *Preventing Nuclear Terrorism: Continuous Improvement or Dangerous Decline?* (2016) : http://belfercenter.ksg.harvard.edu/files/PreventingNuclearTerrorism-Web.pdf
- *The U.S.-Russian Joint Threat Assessment of Nuclear Terrorism*: http://belfercenter.ksg.harvard.edu/files/Joint-Threat-Assessment%20ENG%2027%20May%202011.pdf
  A Worst Practices Guide to Insider Threats: Lessons From Past Mistakes:
  https://www.amacad.org/multimedia/pdfs/publications/researchpapersmonographs/insiderThreats.pdf
- *Nuclear Security Matters:*
  http://nuclearsecuritymatters.belfercenter.org/
- Full text of Managing the Atom publications:
  http://belfercenter.org/mta

For additional information…

An intelligent adversary fundamentally changes probability estimates

- Probability is a method developed for random events – planned human actions are not random
- Earthquakes will not:
  - Preferentially strike the site least able to protect against them
  - Observe the defenses and attempt to bring enough capability to defeat them
  - Consciously plan to cause both primary and backup systems to fail
- Terrorists will seek to do all of those things
  - In security, failures *are not independent*
  - In security, the past is a less reliable guide to the future – adversaries learn and evolve
- Nevertheless, estimating the chance of different events – in concert with other methods – can help structure thinking, identify weak points to be addressed

Assessing the risk of theft at particular nuclear facilities and transports

- Risk of theft at a particular facility or transport:
  - Probability of theft attempt (unknown, presumably reduced by stronger security measures)
  - Probability theft attempt would succeed, determined by
    - Probability distribution of adversary capabilities
    - Capabilities security system can protect against
  - Consequences: probability stolen material could be used to make a bomb, determined by:
    - Adversary capabilities
    - Material quantity
    - Material quality
- Thieves will seek to observe, exploit security weaknesses

Assessing the risk of sabotage at particular nuclear facilities

- Risk of a sabotage attempt at a particular facility or transport:
  - Probability of sabotage attempt (unknown, presumably reduced by stronger security measures)
  - Probability sabotage attempt would succeed, determined by
    - Probability distribution of adversary capabilities
    - Capabilities security system can protect against
    - Difficulty of catastrophic sabotage (related to safety measures)
  - Consequences, determined by:
    - Quantity of radioactivity present
    - Potential to mobilize, disperse the material
    - Nearby populations, economic and other assets
- Saboteurs will seek to observe, exploit security weaknesses

Comparing nuclear safety and nuclear security risks: the historical record

- U.S. safety goal: 1/10,000 per reactor-year chance of major core damage; 1/100,000 chance of major release
  - Obviously haven't met this goal so far
  - 4 reactors with major releases (Chernobyl and 3 at Fukushima Daichi) in 16,000 reactor-years of operation – 1/4,000 reactor-years
  - Other core damage events (TMI, Fermi I…)
  - But goal remains valid – and given horrifying consequences, goal for preventing nuclear terrorist attack should be *more* stringent
- Nuclear theft:
  - ~300 global facilities with HEU or Pu -- ~ 7,500 facility-years over last 25 years
  - ~20 seizures of stolen HEU or Pu in that time (some from same theft)
  - > 1/400 per facility-year
  - Most from Russia (but almost most facilities there); several seizures may be from same theft – but still, shows rate far too high

Comparing nuclear safety and nuclear security risks: the historical record (II)

- Nuclear sabotage
  - During ~16,000 reactor-years of operation:
  - 1 case in which insider placed explosives on steel pressure vessel and detonated them*
  - 1 case (very recent) in which insider sabotage destroyed reactor turbine
  - 1 case in which terrorists overwhelmed and captured the guard force, were in full control for extended period before leaving when off-site response arrived*
  - 1 case of RPG being fired at, hitting reactor
  - Multiple cases of terrorist groups planning attacks on reactors
  - ~ 1 major incident per 3-4,000 reactor-years

Both theft and sabotage risks appear to be very high compared to safety goals

*reactor not yet operational

Attack at Pelindaba, Nov. 8, 2007

- Site with 100s of kilograms of highly enriched uranium (HEU)
- Attack by 2 teams of armed, well-trained men, from opposite sides – evidence of insider help
- One team:
  - Penetrated 10,000-volt security fence
  - Disabled intrusion detectors
  - Went to emergency control center, shot a worker there, who raised first alarm
  - Spent 45 minutes inside guarded perimeter – never engaged by site security forces
  - Left through same spot in fence – never caught or identified
- South Africa has since undertaken major nuclear security upgrades, established regulatory design basis threat
- Lesson: 2 teams of well-armed, well-trained intruders, with insider help, attacking with no warning, is a credible threat

Coping with creative, determined, evolving adversaries

- Nuclear security planning must consider the full spectrum of plausible adversary capabilities
- Adversary capabilities and tactics evolve – DBT from 10 years ago may not match today's threat
- Adversaries may think of attack strategies the defenders have not considered, e.g.:
  - Deception (fake uniforms, IDs, paperwork…)
  - Blocking response forces (e.g., mining the road)
  - Tunneling under or flying over defenses (routine in crimes worldwide)
- Solutions:
  - Consider updating, expanding capabilities in Japan's DBT
  - Assign creative team with "hacker" mentality to probe for weak points
  - Carry out realistic tests with unexpected adversary team tactics

Broad range of demonstrated adversary capabilities and tactics: 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
- Use of deception
  - Uniforms, IDs, forged documents to get past checkpoints, barriers
- Significant covert attack
  - e.g., Pelindaba attackers disabling intrusion detectors
- Use of unusual vehicles or routes
  - e.g., arrival by sea or air
  - e.g., multiple cases of tunneling into bank vaults

Broad range of demonstrated adversary capabilities and tactics: insider threats

- Multiple insiders working together
  - Many cases of theft from guarded facilities worldwide
- 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/corruption
  - Ideological persuasion
  - Blackmail

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

Threats may come from abroad: the Vastbërga heist

- September 2009, armed men steal millions from a cash depot in Vastbërga, Sweden
  - Arrived in stolen helicopter
  - Had automatic weapons, custom-built explosives, custom-built ladders
  - Delayed police arrival with "caltrops" to puncture tires on nearby roads, bag that looked like bomb at police heliport
  - Escaped with millions ~30 minutes after the theft began
  - Eluded pursuit by abandoning helicopter, switching to unknown car
  - Gang was ex-paramilitary from Serbia – half a continent away

Threats may come unexpectedly from within: Aum Shinrikyo

- Japan has long seen itself as a very low-threat country
- But Aum Shinrikyo provides a counter-example
  - Aum had extensive effort to get nuclear weapons
    - Pursued purchase from Russia
    - Bought farm in Australia with U deposits, sought to mine and enrich its own uranium
  - Also had extensive biological program, carried out multiple attempted anthrax attacks (may never have had a deadly strain)
  - Its nuclear, chemical, and biological efforts were unknown to all before its nerve gas attacks in 1995
- Other threats could arise without warning – might focus more than Aum on nuclear material within Japan

A joint U.S.-Russian view

- First ever U.S.-Russian joint threat assessment
- Concludes the danger is real, urgent action is needed to reduce it
- Endorsed by broad range of retired military, intelligence experts

http://belfercenter.ksg.harvard.edu/publication/21087/

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

- Government studies – in the United States and elsewhere – have repeatedly concluded that a sophisticated terrorist group could plausibly make a nuclear bomb.

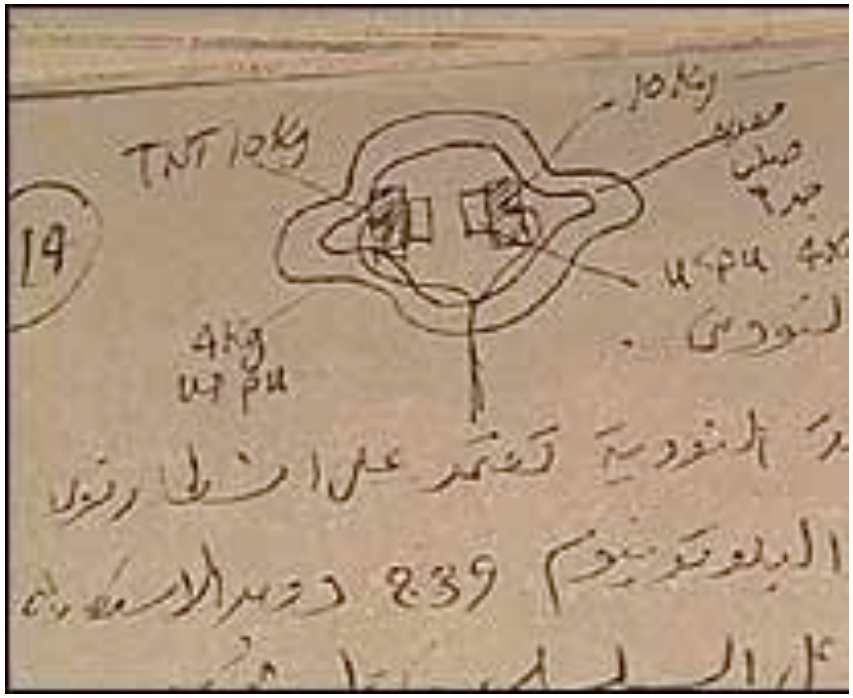
  "A small group of people, none of whom have ever had access to the classified literature, could possibly design and build a crude nuclear explosive device... Only modest machine-shop facilities that could be contracted for without arousing suspicion would be required."

  -- *U.S. Office of Technology Assessment, 1977*

- U.S. security rules for some types of material based on preventing adversaries from setting off a nuclear blast *while they are still in the building*

Al Qaeda has actively sought to get nuclear bombs

- Repeated attempts to purchase nuclear material or nuclear weapons
- Repeated attempts to recruit nuclear expertise
- Focused program that reported directly to Zawahiri
- Reached the point of carrying out crude (but sensible) explosive tests for the nuclear program in the Afghan desert



Source: CNN

Al Qaeda has actively sought to get nuclear bombs (II)

- 2001: Bin Laden and Zawahiri meet with 2 senior Pakistani nuclear scientists to discuss nuclear weapons
  - Now-sanctioned UTN network was helping with chemical, biological, nuclear efforts – also offered nuclear weapons technology to Libya
- 2003:
  - bin Laden gets *fatwa* from radical Saudi cleric authorizing use of nuclear weapons against civilians
  - Saudi al Qaeda cell negotiating to buy 3 nuclear devices – if "Pakistani expert" confirms they are real
- 2008: Zawahiri reiterates, elaborates arguments of nuclear *fatwa*

Source: Reuters

Key core al Qaeda nuclear operatives still at large

Ayman al Zawahiri  Source: FBI	Now head of the group. Nuclear project reported directly to him.
Abdul Aziz al-Masri  Source: NCTC *aka* Ali Sayyid Muhamed Mustafa al-Bakri	CEO of al Qaeda's nuclear program, oversaw explosives experiments in Afghanistan.

Sayf al-Adel  Source: FBI	Senior al Qaeda operational planner, reportedly personally approved attempted purchase of 3 nuclear bombs in 2003
"Pakistani Nuclear Expert" 	2003 communications from al Qaeda leaders reportedly approved purchase of nuclear devices if the Pakistani expert confirms they are real – U.S. Government has never identified or found this expert

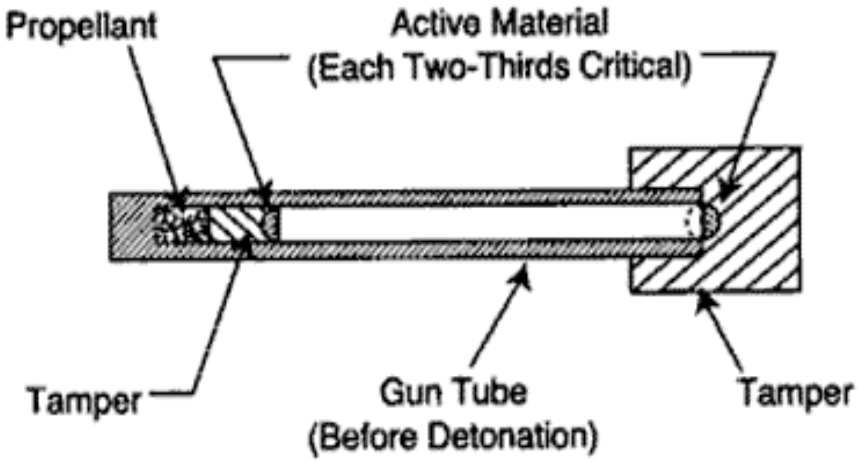
North Caucasus terrorists have pursued nuclear and radiological terrorism

- Multiple cases:
  - 2 cases of teams carrying out reconnaissance at nuclear weapon storage sites – 2 more on nuclear weapon transport trains
  - Repeated threats to attack nuclear reactors – terrorists who seized Moscow theater in 2002 considered seizing reactor at the Kurchatov Institute
  - Repeated threats to use radiological "dirty bombs" – buried Cs-137 source in Moscow park
  - Captured documents indicate plan to seize a Russian nuclear submarine (possibly with nuclear weapons on board)

Source: Public Broadcasting Service

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 plutonium) more difficult, still conceivable (especially if they got help)
  - Doesn't need to be as complex as Nagasaki bomb



Source: NATO

Doesn't take a Manhattan Project -- >90% of the effort was focused on producing nuclear material. And making a crude terrorist bomb is *far* easier than making a safe, reliable weapon

Has the threat disappeared?

- Bin Laden dead, core al Qaeda profoundly disrupted, key North Caucasus terrorist leaders killed
- Nuclear security is substantially improved at many sites – many sites have no weapons-usable material left
- *But:*
  - al Qaeda has proved resilient – could resurge
  - "Emirate Kavkaz" terrorists in North Caucasus strengthening
  - Other groups have pursued nuclear weapons as well – with 2-3 groups having gone the nuclear path in last 15 years, cannot expect they will be the last
  - *Intent* is enduring; *capability* may increase as technology spreads; strong nuclear security needed to remove *opportunity*
  - The problem of nuclear terrorism and the need for nuclear security will be with us for decades – no room for complacency

The scale of the catastrophe

- Tens of thousands killed; tens of thousands more burned, injured, irradiated
  - Radioactive fallout would require large-scale evacuation
- Terrorists may claim they had more bombs hidden in cities, threaten to detonate them unless their demands were met
  - Potential for widespread panic, flight from major cities, resulting economic and social chaos
- Huge pressure on leaders of attacked state to take any action necessary to prevent further attacks – and to retaliate
  - Effects on international affairs likely far larger than 9/11

Notions of sovereignty and civil liberties may be radically altered – every state's behavior affects every other

Terrorists might be able to get plutonium or HEU

- ~20 documented cases of theft and smuggling of plutonium or HEU, some in kilogram quantities
  - Most recent seizures: Georgia 2010, Moldova 2011
  - Even small thefts suggest vulnerabilities that could be exploited for larger thefts
  - Small seizures may be samples of larger stocks
- Major progress in improving nuclear security
  - Dozens of sites with major security upgrades
  - Dozens of sites all material removed
- But many weaknesses remain, in many countries
  - Protection against only modest threats
  - Lack of on-site armed guards
  - Limited insider protection

Source: Reuters, from Georgian Interior Ministry

Immense global stockpiles of nuclear weapons and weapons-usable materials

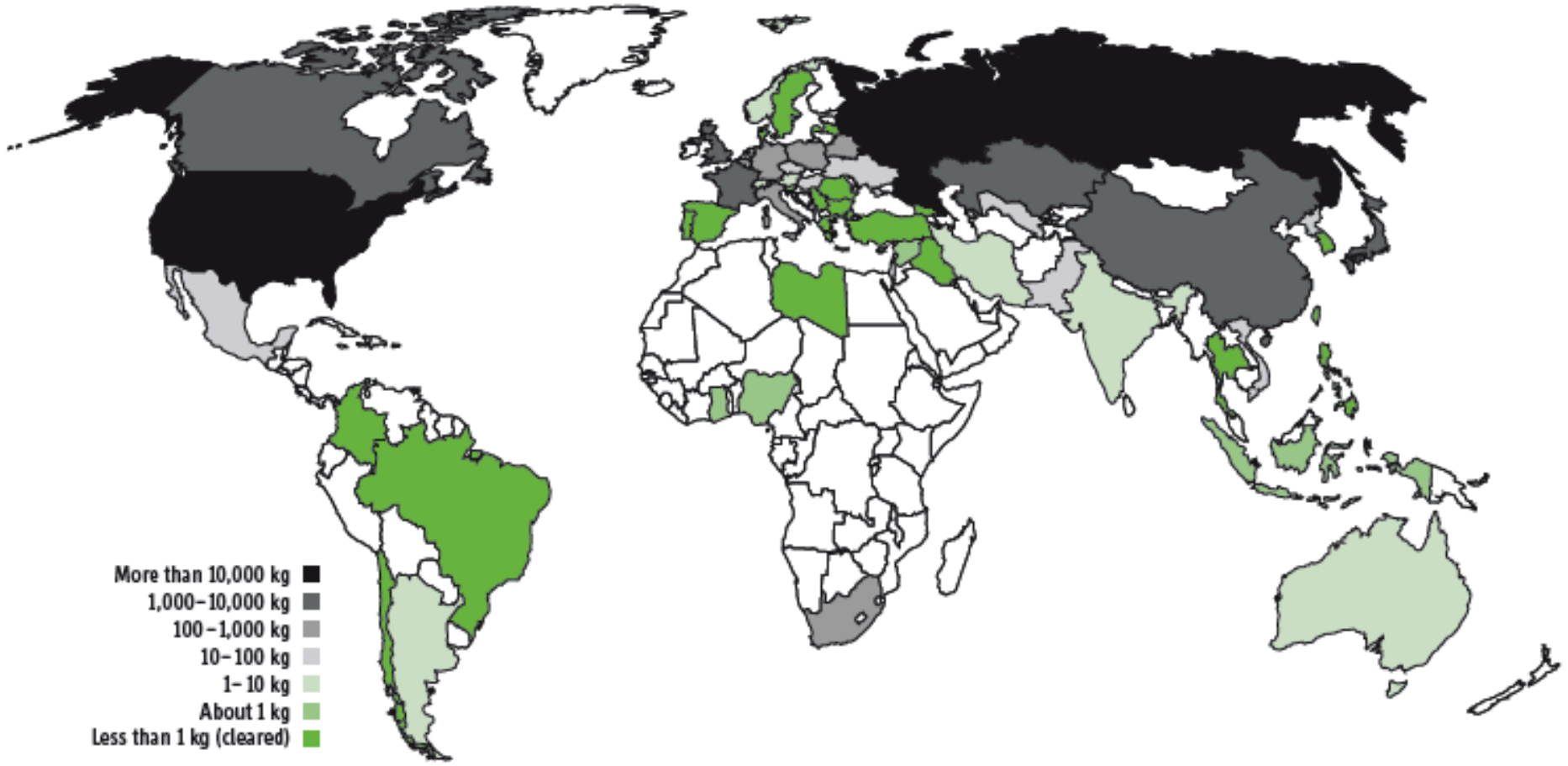
- ~17,000 assembled nuclear weapons still exist
  - All but ~1,000 in U.S. and Russian stockpiles
- Global stock of separated plutonium is nearly 500 tonnes
- Global stock of HEU is almost 1,400 tonnes (+/- 125 tonnes)
- Nuclear weapons stored at >100 sites
- Weapons-usable nuclear material in hundreds of buildings in dozens of countries around the world

W-48 nuclear artillery shell, one of many thousands of tactical nuclear weapons that have been dismantled

Source: U.S. Department of Energy

Theft of 0.01% of world stockpile could cause a global catastrophe

Widely distributed global stockpiles



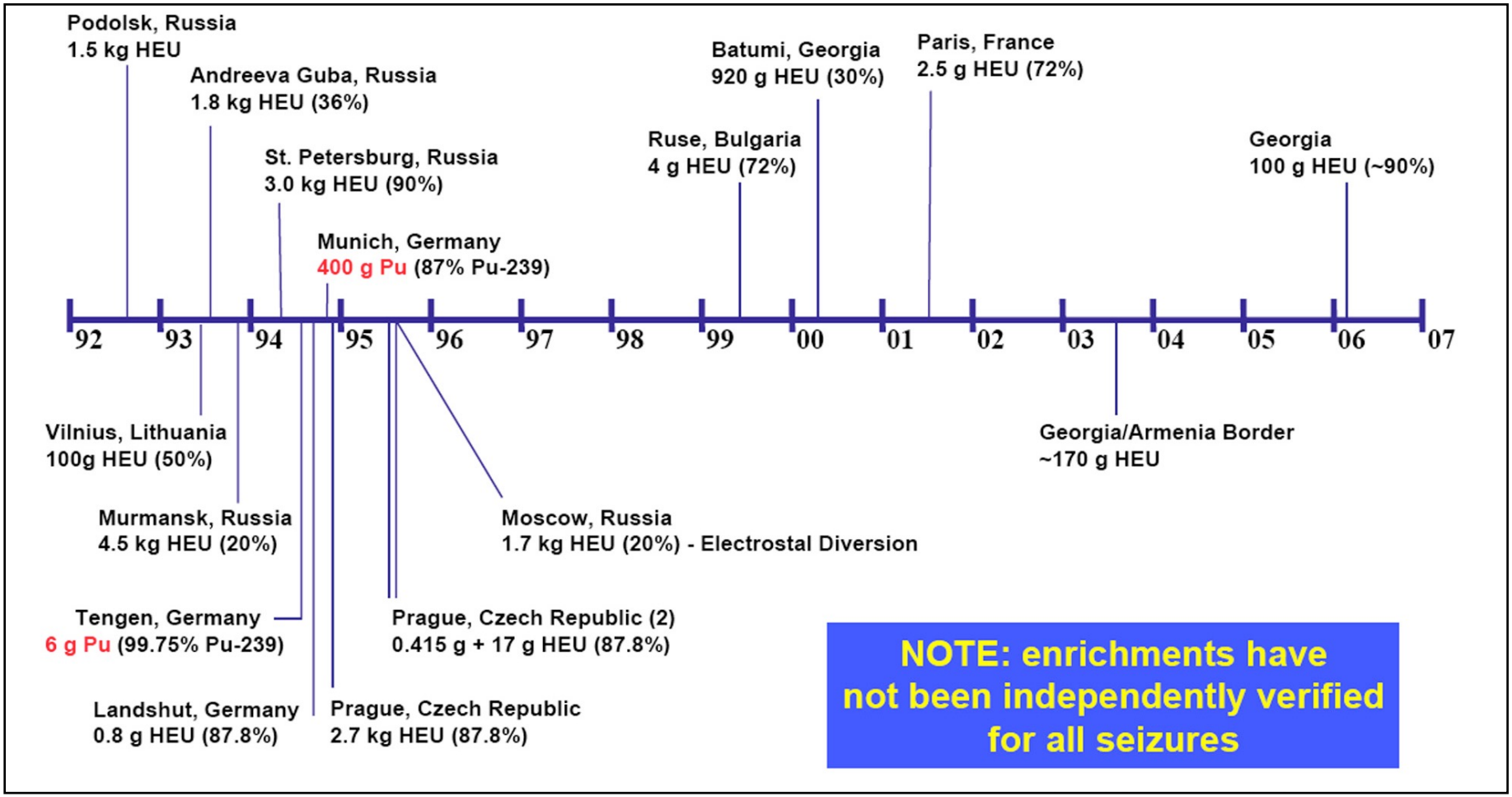
Global Distribution of Civilian HEU Stockpiles

Source: International Panel on Fissile Materials, *Global Fissile Materials Report 2011*

What is the evidence that current nuclear security is inadequate?

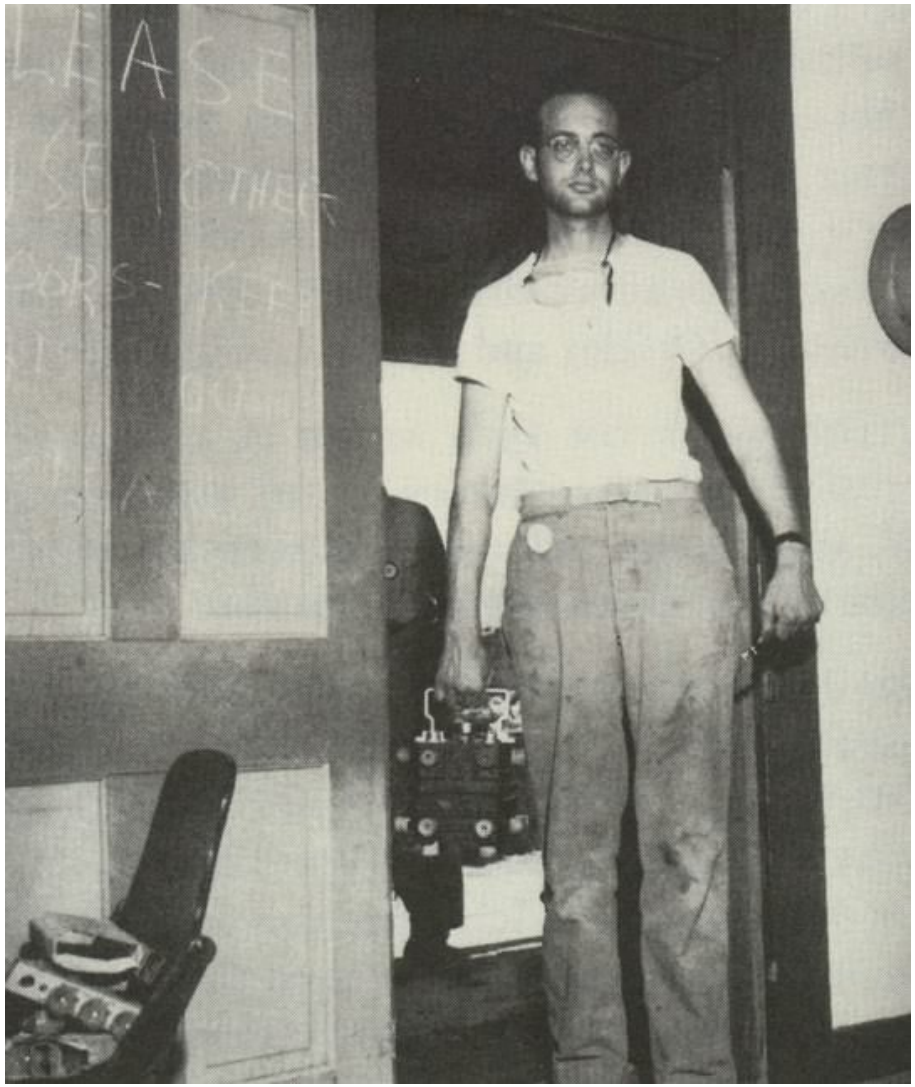
- Continuing seizures of weapons-usable material
  - ~20 real cases involving HEU or plutonium since 1992
- "Red team" tests indicate security systems can be defeated by intelligent adversaries looking for weak points
  - Repeated cases in U.S. tests – though U.S. has among the most stringent security requirements in the world
  - Most other countries do not carry out such tests
- Successful thefts and attacks at well-secured non-nuclear facilities – demonstrating adversary capabilities
  - Repeated cases of use of insiders, covert outsider attacks, unusual tactics, succeeding in stealing from/attacking heavily guarded sites (e.g., banks, military bases, diamond centers…)
  - Existing nuclear security measures in many countries demonstrably insufficient to protect against such adversary capabilities

Documented seizures, 1992-2006 (more seizures in 2010, 2011)



Source: Los Alamos National Laboratory, Tom Bielefeld

Nuclear material is not hard to smuggle – plutonium box for first-ever bomb



Source: Los Alamos

Recent incidents of concern

- U.S., 2012: 82-year-old nun and 2 other protestors penetrate 4 layers of fences (3 alarmed) get right to wall of building holding enough HEU for 1000s of bombs – cameras broken, alarms ignored, major breakdown of security culture
  - Lesson: Can never be complacent about nuclear security, even in countries with strong security rules and large security spending
- Moldova, 2011: Seizure of stolen HEU, from large group, with connection to real buyer – Moldovans report smugglers still at large have at least 1 kilogram HEU
  - Lesson: Smuggling of potential nuclear bomb material an on-going problem – smugglers may be getting more sophisticated
- South Africa, 2007: Attack on HEU site at Pelindaba by 2 armed teams, one team penetrated 10,000-volt security fence, disabled alarms, shot staffer at emergency center
  - Lesson: Nuclear sites must be able to defend against more than one team of sophisticated adversaries, with insider knowledge

International assessments of the danger of nuclear terrorism

"Nuclear terrorism is one of the most serious threats of our time. Even one such attack could inflict mass casualties and create immense suffering and unwanted change in the world forever. This prospect should compel all of us to act to prevent such a catastrophe."

- U.N. Secretary-General Ban-Ki Moon, 13 June 2007

"The gravest threat faced by the world is of an extremist group getting hold of nuclear weapons or materials."

- then-IAEA Director-General Mohammed ElBaradei, 14 September 2009

"We have firm knowledge, which is based on evidence and facts, of steady interest and tasks assigned to terrorists to acquire in any form what is called nuclear weapons, nuclear components."

- Anatoly Safonov, then counter-terrorism representative of the Russian president, former head of the FSB, 27 September 2007

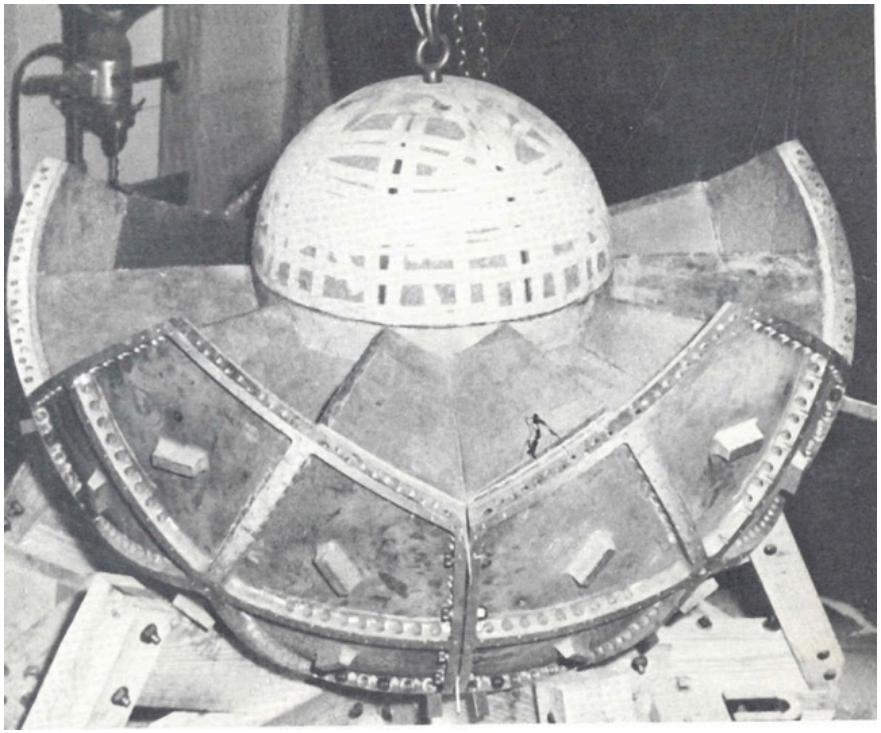
Summary: the nuclear terrorist threat

	Yes	No
❑ Do terrorists want nuclear weapons?	☑	☐
❑ Is it conceivable terrorists could make a crude bomb if they got the material?	☑	☐
❑ Is there material that might be vulnerable to theft and transfer to terrorists?	☑	☐
❑ Is it likely that terrorists, if they had a crude device, could smuggle it to Moscow, London, Paris, Washington, or New York?	☑	☐

The probability may not be high – but no one would operate a nuclear reactor upwind of a city if it had a 1/100 chance each year of a catastrophic radiation release – risk of a terrorist nuclear bomb may well be higher

Implosion-type bombs

- Much more efficient than gun-type bombs
- Only type that offers substantial yield with plutonium
- Significantly more complex to design and build
  - More difficult for terrorists, still conceivable (esp. if they got knowledgeable help)
- Main approaches require explosive lenses, millisecond timing of multiple detonations
- Some approaches less complex than Nagasaki bomb



Source: Rhodes, *The Making of the Atomic Bomb* (orig. Los Alamos)

Hard parts for a crude terrorist bomb

- #1: Getting weapons-usable nuclear material
  - Once they have that, 80% or more of the way there
- Others:
  - Processing material into appropriate form
  - Casting and machining (U and Pu difficult materials – esp. Pu)
  - Building explosives, reflector, etc., getting them to work
  - For implosion weapons of the standard type:
    - Precise shaped explosives with very precise timing
    - Need to crush material to denser, more critical form, not flatten it into a pancake
    - Neutron generator to provide shower of neutrons at best moment
  - All this requires an ability to recruit/train skilled personnel, raise money, sustain an organizational effort over a period of time…

Some scenarios might allow some steps to be bypassed

Two key potential bomb materials

- Highly enriched uranium (HEU)
  - Must separate nearly identical U-235 and U-238 isotopes
  - Nearly all techniques based on their small difference in mass
  - Gaseous diffusion
  - Centrifuges
  - Other: calutrons, laser…
- Plutonium
  - Cause U-238 to absorb neutrons (typically in a reactor)
  - Chemically separate resulting plutonium from the rest (reprocessing)
- A few other isotopes could support explosive nuclear chain reactions, have never been used

None of these materials occur in nature; all are extraordinarily difficult to produce

Some (sometimes misleading) terms to remember

- *Highly enriched uranium (HEU)*
  - Uranium with at least 20% U-235
  - As opposed to *natural uranium* (0.7% U-235), *low-enriched uranium* (LEU, typically 4-5% U-235), or *depleted uranium* (<0.7% U-235)
- *Weapons-grade uranium*
  - Uranium with ~90% U-235
  - But bombs can be made with material far below weapons-grade
- *Weapons-grade plutonium*
  - Plutonium with ~ 90% Pu-239
  - As opposed to *reactor-grade* plutonium (much less Pu-239) – contained in spent fuel from typical nuclear power reactors
  - Weapons-makers prefer weapons-grade plutonium, but reliable, effective weapons can also be made with reactor-grade plutonium (once reprocessed from spent fuel)

Reactor-grade plutonium is weapons-usable

- Higher neutron emission rate:
  - For Nagasaki-type design, even if neutron starts reaction at worst possible moment, "fizzle yield" is ~ 1kt – roughly 1/3 destruct radius of Hiroshima bomb – more neutrons won't reduce this
  - Some advanced designs are "pre-initiation proof"
- Higher heat emission:
  - Various ways to deal with – for example, plutonium component can be inserted into weapon just before use (as in early U.S. designs)
- Higher radiation:
  - Can be addressed with greater shielding for fabrication facility
  - Last-minute insertion of plutonium component again

Reactor-grade plutonium is <u>not</u> the <u>preferred</u> material for weapons, but any state or group that can make a bomb from weapon-grade plutonium can make one from reactor-grade

The amounts of material required are small

- For simple "gun-type" bomb (with reflector): ~ 50-60 kg of HEU (Hiroshima bomb was 60 kg of 80% enriched material)
  - Fits in two 2-liter bottles
- For 1st-generation implosion bomb:
  - ~6 kg plutonium (Nagasaki)
  - ~ 3x that amount of HEU

The size of the plutonium core for the Nagasaki bomb

Source: Robert del Tredici

What's true? Reasons for skepticism about the nuclear terrorism threat

- States have had great difficulty getting nuclear weapons, surely it would be harder for terrorists
  - Hardest part for states is making the nuclear material – 90% of Manhattan Project
  - Making safe, reliable weapons that can be delivered by missile or aircraft is *far* harder than making crude terrorist bomb
- Terrorist attacks are mostly not very sophisticated
  - But there is a spectrum – some terrorist groups *have* used sophisticated explosive designs
  - Significant numbers of well-trained engineers and scientists have worked with terrorist groups
- Greatly weakened al Qaeda could not organize a nuclear bomb effort
  - Killing, capture, disruption of much of top leadership *does* reduce the risk – but modest cell far from the drone strikes could still be pursuing a nuclear effort

What's true? Reasons for skepticism about the nuclear terrorism threat (II)

- U.S. intelligence has exaggerated terrorist threats – including in the lead-up to war in Iraq
  - Absolutely correct – skepticism justified. *But* notable that *both* George W. Bush and Barack Obama identify nuclear terrorism as greatest threat to U.S. national security
  - Wide range of other countries (both nuclear weapon states and non-nuclear-weapon states) have reached similar conclusions
- Terrorists could not plausibly get nuclear material
  - Ongoing seizures suggest danger still exists
  - For most seizures, material was never noticed to be missing --how many other thefts have *not* been detected?
- Terrorists not likely to get state support
  - Probably true – states unlikely to hand such power over to terrorist groups they cannot control
  - But state support helpful, not essential, to terrorist nuclear effort

Nuclear terrorism: the good news

- No convincing evidence any terrorist group has yet obtained a nuclear weapon or the materials and expertise needed to make one
  - Despite many claims
- No evidence any state has helped terrorists with nuclear weapons
- Making a nuclear bomb is clearly not "easy"
  - Al Qaeda and Aum Shinrikyo, both sophisticated, well-funded groups, appear to have faced major hurdles
- Overall, threat is probably lower than 10 years ago
  - Many nuclear sites have much better security, or all nuclear material removed
  - Al Qaeda substantially disrupted
  - *But what may be happening without being detected?*

Did you know? Real incidents related to nuclear terrorism

- Events that have genuinely occurred:
  - A large-scale terrorist attack on a U.S. nuclear weapons base
  - A terrorist attack on a nuclear facility (not yet operational) in which the armed guard force was overwhelmed, terrorists were in control of facility for an extended period
  - More than a dozen real acts of sabotage at nuclear facilities
    - None apparently intended to cause large radioactive release
    - One involved an insider bringing explosives into a nuclear reactor, placing them on the steel pressure vessel head, and detonating them (before the facility became operational)
    - One involved firing a rocket-propelled grenade at a nuclear facility
  - A Russian businessman offering $750,000 for stolen weapon-grade plutonium, for sale to a foreign client

Terrorists might be able to get material: The 2011 Moldovan HEU case

- 27 June, 2011: Moldovan officials arrest 6 people for nuclear smuggling
  - 4.4 grams weapon-grade HEU seized
  - Smugglers claim to have access to 9 kilograms of HEU, willing to sell for $31 million
  - Smugglers also claim to have access to plutonium
  - Smuggling through breakaway region of Transnistria
  - Russian leader of group and African buyer are still at large (appears to be first case in some time with serious buyer involved)
  - Moldovan officials report that "members of the ring, who have not yet been detained, have one kilogram of uranium"
  - Little is publicly known about specific characteristics or origins of the material, capabilities of the smugglers, identity of the buyer…

Terrorists might be able to get material: Widely varying nuclear security

- No binding global standards for how secure nuclear weapons or nuclear materials should be
- Pakistan:
  - Small, heavily guarded stockpile
  - But immense threats – potentially huge outsider attacks, corrupt insiders, some with jihadist sympathies
- Russia:
  - *Dramatically* improved security compared to 15 years ago
  - Cooperative upgrades nearly complete
  - *But*, world's largest stockpiles in world's largest number of buildings and bunkers; underinvestment in sustainability; security culture still needs work; regulations weak; widespread insider corruption
- HEU-fueled research reactors
  - ~120 in > 30 countries, some only night watchman, chain-link fence

Some recent anecdotes of insecurity

- Russia: Gen-Major Victor Gaidukov, commander of a nuclear weapon storage site, fired over accusations of accepting >$300,000 in bribes (2010)
- Pakistan: Brig.-Gen. Ali Khan arrested for ties to Islamic extremists (2011)
- Belgium: Peace activists break into nuclear weapon storage base, spend >1 hour there before being detected and stopped (2010)
- United States: Bomber flies across the country with 6 nuclear weapons on board, no one knows – checks failed (2007)

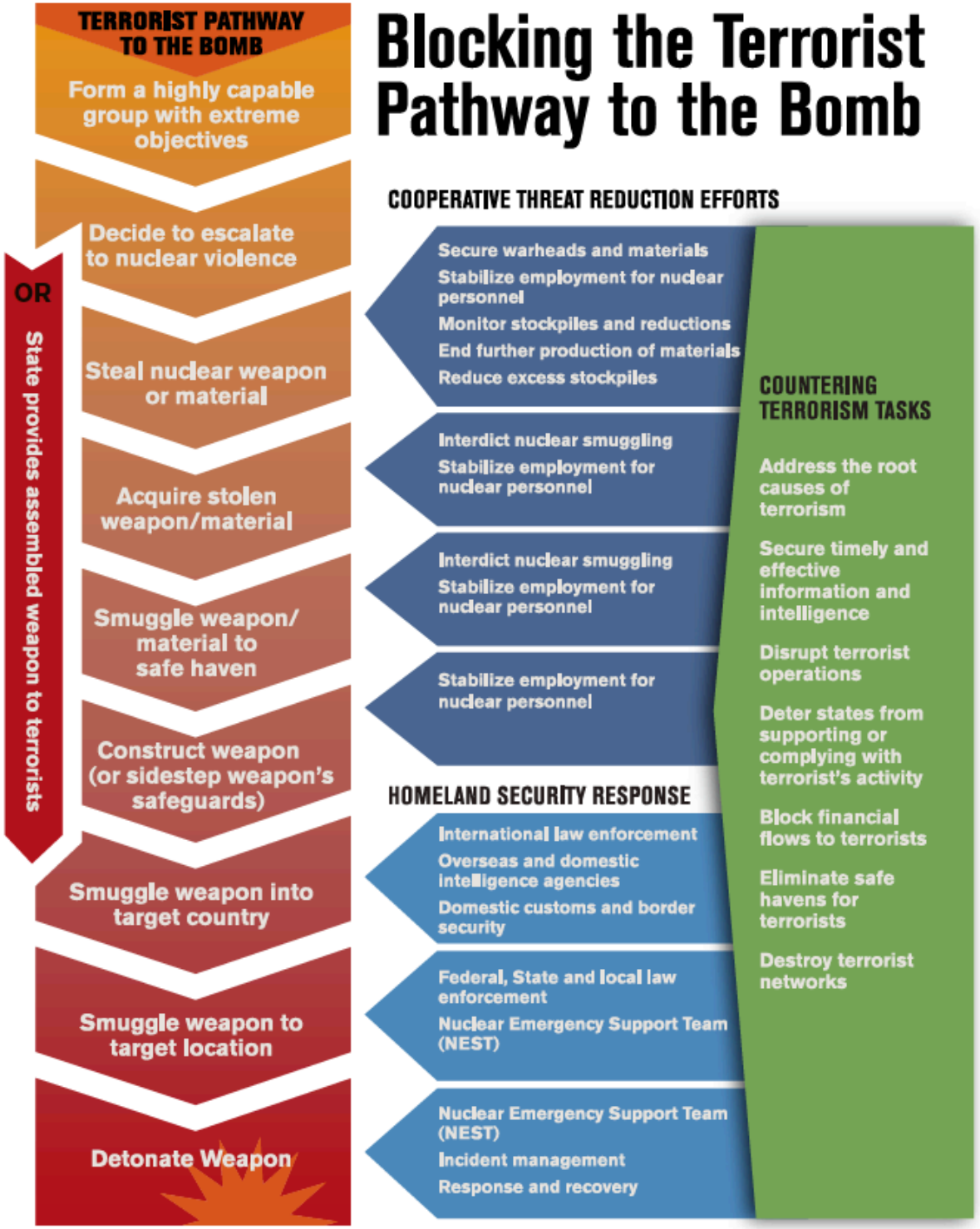
North Korea and Iran are likely small parts of the nuclear terrorism problem

- Nuclear security:
  - North Korea has only a few bombs' worth of plutonium in a tightly controlled garrison state – theft very unlikely
  - Iran has not begun to produce weapons-usable material – has only a small amount of HEU research reactor fuel
- Conscious state transfer:
  - Regimes bent on maintaining power unlikely to take the immense risk of providing nuclear bomb material to terrorist groups who might use it in a way that would provoke overwhelming retaliation
  - Transfers to other *states* – who are likely to be deterred from using nuclear weapons – a very different act
- High-level "rogues" within states
  - As stocks of material grow, could an "A.Q. Kim" sell secretly?
- State collapse:
  - Could have worrisome "loose nukes" scenario

Spread of nuclear power need not increase terrorist nuclear bomb risks

- Most nuclear reactors do not use nuclear material that can readily be used in nuclear bombs:
  - Low-enriched uranium fuel cannot be used to make a nuclear bomb without technologically demanding further enrichment
  - Plutonium in spent fuel is 1% by weight in massive, intensely radioactive fuel assemblies
- Reprocessing (separating plutonium from spent fuel) could increase risks, requires intensive security and accounting
  - Poor economics, few additional countries pursuing – South Korea and China only countries currently considering shift
  - Reprocessing does not solve the nuclear waste problem – still need a nuclear waste repository
- Power reactors do pose potential targets for sabotage
  - Sabotage would mainly affect nearby countries, global nuclear industry
  - As with nuclear theft, strong security measures can reduce the risk

Blocking the terrorist pathway to the bomb



Source: Bunn, Securing the Bomb 2010: Securing All Nuclear Materials in Four Years (2010)

New steps to reduce nuclear weapons and materials sites

- HEU:
  - Still some 120 research and training reactors using HEU fuel or targets – Russia has world's largest share, far more than needed
  - Should agree on target of *a complete phase-out* of all civil use of HEU
  - Tons of civilian HEU not currently being addressed – should all be put on a path to elimination
  - Should create new incentives to shift toward international sharing of small number of high-capability, LEU-fueled reactors (or accelerators), shut down remainder. IAEA estimate: ~80% of current reactors not needed
- Plutonium:
  - Should agree to end build-up of stocks, limit number of sites
- Military stocks
  - Need new initiatives to consolidate and reduce these as well
  - U.S. saving hundreds of millions a year on safety and security costs

What would nuclear security success look like?

- Number of sites with nuclear weapons, HEU, or separated plutonium greatly reduced
- All countries with HEU, Pu, or major nuclear facilities put in place *at least* a "baseline" level of nuclear security
  - Protection against a well-placed insider, a modest group of well-trained and well-armed outsiders (able to operate as more than one team), or both outsiders and an insider together
  - Countries facing higher adversary threats put higher levels of security in place
- Strong security cultures in place, focused on continual improvement, search for sustainable excellence
- Measures in place to confirm strong security performance
  - Effective regulation, inspection, enforcement
  - Regular, realistic performance tests – including "red teams"
  - Independent, international review – becoming the norm

Essential elements of an "appropriate effective" physical protection system

- A *design basis threat* reflecting today's threats
- Effective *regulation* requiring all facilities with potential bomb material or posing a catastrophic sabotage risk to have security capable of defeating the DBT
  - Backed up by inspections, and enforcement
  - Ideally including *realistic tests* of the system's ability to defeat outsider and insider threats
  - Effective *control and accounting* of nuclear material
- A strong *security culture*, to ensure that all relevant staff understand the threat and the importance of security
- *Police and intelligence* efforts focused on ensuring that nuclear conspiracies will be detected
- *Regular review and adaptation* to ensure the system adapts to changing threats and opportunities

The international nuclear security framework is insufficient

- Binding agreements
  - 1980 Physical Protection Convention and 2005 Amendment
    - Parties must have a rule on nuclear security – but what should it say?
    - 2005 Amendment not likely to enter into force for years to come
  - 2005 Nuclear Terrorism Convention
    - All parties to take "appropriate" nuclear security measures -- unspecified
  - UNSC Resolution 1540
    - All states must provide "appropriate effective" nuclear security -- unspecified
- International recommendations
  - IAEA "Nuclear Security Series," especially INFCIRC/225
    - More specific, but still quite general – should have a fence with intrusion detectors, but how hard should they be to defeat?
    - Compliance voluntary (though most countries do)
- Technical cooperation and funding
  - Nunn-Lugar, comparable programs
  - Global Partnership
  - Secrecy, bureaucracy often make cooperation difficult

The international nuclear security framework is insufficient (II)

- Cooperative frameworks
  - Global Initiative to Combat Nuclear Terrorism
    - 82 nations participating
    - Helps to convince countries of reality of threat
    - Sharing of experience, best practices, capacity-building
    - Modest focus on upgrading nuclear security
  - Proliferation Security Initiative
    - Unlikely to stop smuggling of suitcase-sized items
  - Nuclear Security Summit process
    - Bringing together leaders from ~50 countries
    - Commitment to secure all vulnerable nuclear material in four years
    - Vague group commitments – more specific national commitments
- The IAEA role
  - Developing recommendations, peer reviews, assistance, data
    - All voluntary, largely limited to non-nuclear-weapon states

Many tiles in the mosaic – but is it yet a beautiful picture?
No common baseline of nuclear security for all Pu and HEU

Nuclear security is the foundation for the three pillars of the NPT

- Disarmament:
  - Nuclear weapon states will not disarm if insecure nuclear material could allow other states or terrorist to rapidly get nuclear weapons
- Peaceful uses:
  - Nuclear energy will not gain needed support unless people are confident that it is safe and secure
- Nonproliferation:
  - Efforts to stop the spread of nuclear weapons will not work if Insecure nuclear material offers states or terrorist groups a rapid path to the bomb

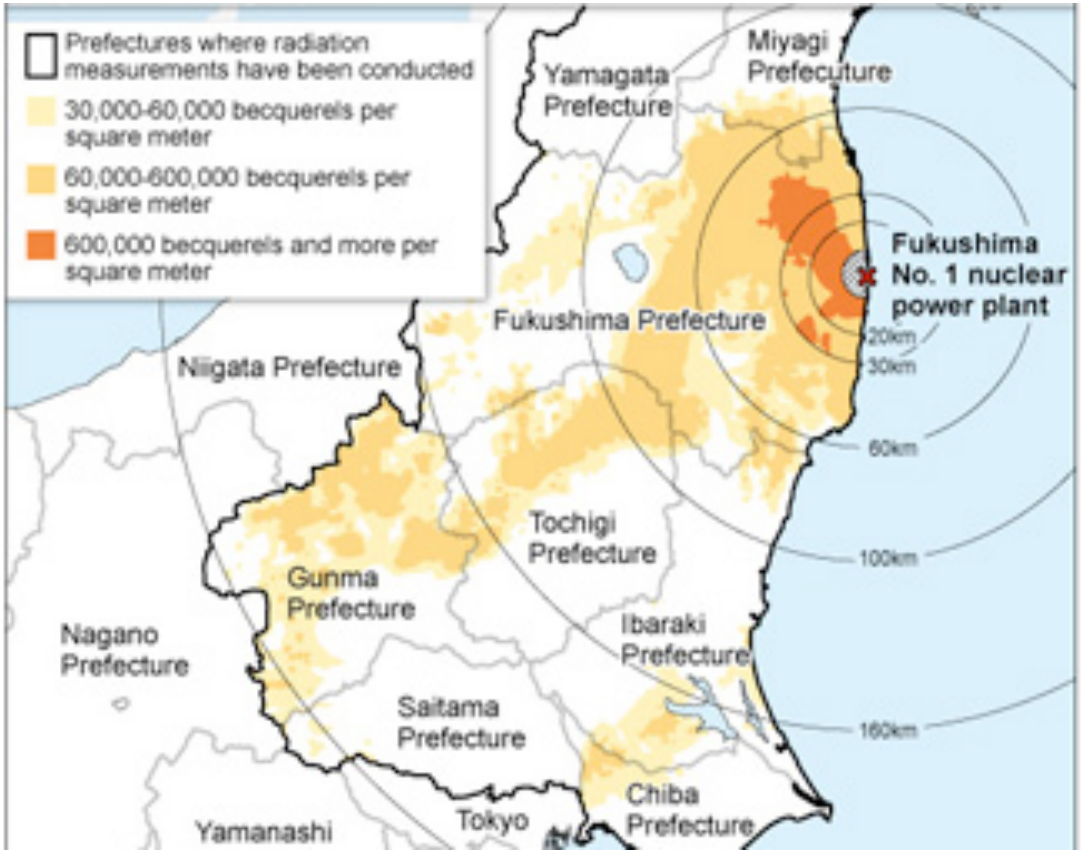
In all these areas, nuclear security is important to the security of all countries around the world

Belief in the threat – the key to success

- Effective and lasting nuclear security worldwide will not be achieved unless key policymakers and nuclear managers around the world come to believe nuclear terrorism is a real threat to *their* countries' security, worthy of investing their time and resources to address it
- Steps to convince states this is a real and urgent threat:
  - Intelligence-agency discussions – most states rely on their intelligence agencies to assess key security threats
  - Joint threat briefings – by their experts and our experts, together
  - Nuclear terrorism exercises and simulations
  - "Red team" tests of nuclear security effectiveness
  - Fast-paced nuclear security reviews – by teams trusted by the leadership of each country
  - Shared databases of real incidents related to nuclear security, capabilities and tactics thieves and terrorists have used, lessons learned

Terrorists have also considered sabotage of major nuclear facilities

- al Qaeda senior leadership has explored the possibility of sabotaging nuclear facilities
- Chechen terrorists have threatened and planned attacks on nuclear facilities
- Fukushima showed that destroying both main and backup cooling can lead to major release, create widespread fear



Source: Asahi Shimbun, from MEXT

The threat of nuclear sabotage

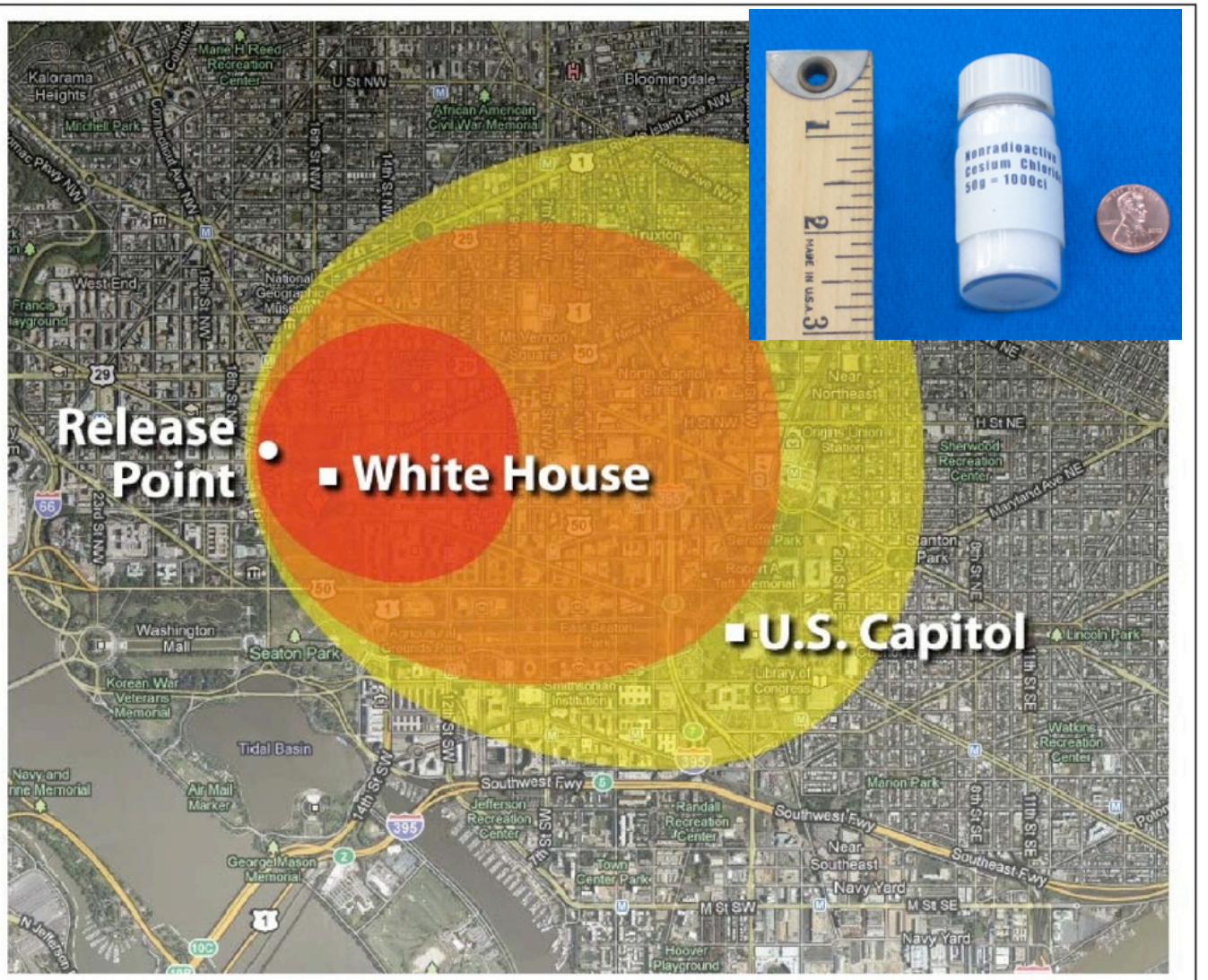
- Most nuclear power plants protected by security forces, containment vessels, and redundant safety systems
- *But,* levels of security vary widely:
  - Some reactors have no (or few) on-site armed guards
  - Few civilian facilities are designed to cope with 9/11 threat -- multiple, coordinated teams, suicidal, well-trained, from a group with substantial combat and explosives experience
  - Some reactors do not have Western-style containments, few redundant safety systems
- *If* attackers could successfully destroy multiple safety systems, reactor could melt down, breach containment, spread radioactive material – as at Fukushima
- Similarly, *if* attackers could successfully drain the water from a densely packed spent fuel pool, real risk that fuel could get hot enough to catch fire -- potential Chernobyl-scale disaster

The threat of "dirty bombs"

- Dirty bomb could be very simple -- dynamite and radioactive material together in a box
  - Other simple means to disperse radioactive material more effective
- Dangerous radioactive sources in use for valuable civilian purposes in hospitals, industry, agriculture
  - Even large sources often have minimal security
- "Weapons of mass disruption" – not mass destruction
  - Would cause zero to a few near-term radiation deaths, potentially a few hundred long-term cancer deaths (undetectable against natural cancer background)
  - *But,* fear of anything "radioactive" could create panic
  - Expensive, disruptive – potentially many blocks would have to be evacuated, cleaned up (possibly 10s of billions in costs)

Cs-137 "dirty bomb"

- Potentially dangerous sources used in hospitals, industry, in almost every country
- Al Qaeda, Chechens have repeatedly considered dirty bomb attacks



Effects and Actions

	Area km²	Area mi	Equivalent Dose (rem)	Exceeds relocation PAG for which year:	Population	All Cancers	Fatal Cancers
	2.10	0.81	>2.00	First year only	38,000	233	159
	7.60	2.93	>0.500	Any subsequent year	94,700	278	189
	13.2	5.10	>5.00	50 years (cumulative)	125,000	461	314

Areas and counts are cumulative. RDD detonated at 38.9 N, 77.0 W. PAG: Protective Action Guide

Source: Congressional Research Service, modeling by Sandia National Laboratories, 2010

Dealing with the "dirty bomb" threat

- Better control, accounting, security for radioactive sources:
  - All high-priority sources worldwide should be accounted for, regulated, and have basic security measures (strong locks, alarms, etc.) throughout their life-cycle – IAEA "Code of Conduct"
  - Improved transport security especially needed
  - Retrieve, safely dispose of disused sources
  - Scores of countries worldwide have inadequate controls
- Radiation detection at ports, borders
- Improved capacity to detect, assess, respond to attack
  - Need training, regular exercises, for first responders
  - Develop improved urban decontamination technologies
- Most important: communication strategy to limit panic, tell public how to respond – complicated by past gov't lies