Using Nuclear Materials to Prevent Nuclear Proliferation

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Outline:
1. How does a physicist end up in government?
2. What do you do when you get there?
3. Enhancing nuclear weapons material security in Russia.
4. Other projects and lessons learned.

How does a physicist end up in government?

- Science and Engineering Fellowships of the American Association for the Advancement of Science (AAAS).
- Places scientists in all areas of government from the Department of Defense to Congress to the Justice Department.
  - Brings scientific expertise into government.
  - Train scientists to solve policy problems within government.
- Defense Policy Fellowship
  - Fellows work on a variety of issues related to defense policy, technology applications, defense systems analysis and support, and program oversight and management.
  - Activities include managing research and development programs and investigating technical questions influencing defense policy.

What do you do when you get there?

- The Defense Threat Reduction Agency (DTRA)
  - DTRA's mission is to reduce the threat to the United States and its allies from nuclear, biological, chemical (NBC), conventional and special weapons.
  - Develops and manages programs in areas from nuclear arms control to on-site inspections to biological warfare response.
- The Advanced Systems and Concepts Office (ASCO)
  - Conducts analyses of emerging threats related to weapons of mass destruction (WMD) as well as future technologies and concepts to deal with them.
  - Think tank consisting of scientists, engineers, and other experts that interact with all levels of government.
  - Performed and managed studies on fissile material security, the Comprehensive Test Ban Treaty, cooperative threat reduction, and others.

Nuclear Weapons 101

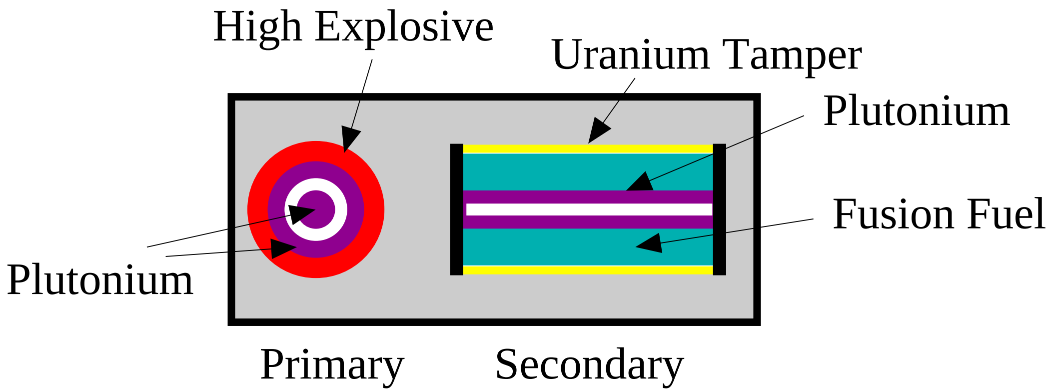
- Fissile materials (^{235}U, ^{233}U, ^{239}Pu) are used to make weapons of devastating power.
- Only about 8 kg of plutonium or 25 kg of highly-enriched uranium (HEU) is needed is needed to produce a weapon.
- As each nucleus fissions, it emits 2 or so neutrons plus lots of energy in the form of photons. For example,

$$^{235}U + n \rightarrow {}^{236}U^* \rightarrow {}^{140}Xe + {}^{94}Sr + 2n + \approx 200\ MeV$$

- Most of the neutrons leave the material without striking any other nuclei under normal conditions of temperature and density.
- Increasing the density will create a ‘chain reaction’ where the emitted neutrons cause other fissions in a self-propagating process.

Nuclear Weapons 101

- A ‘typical’ US-Russian, two-stage, thermonuclear weapon.



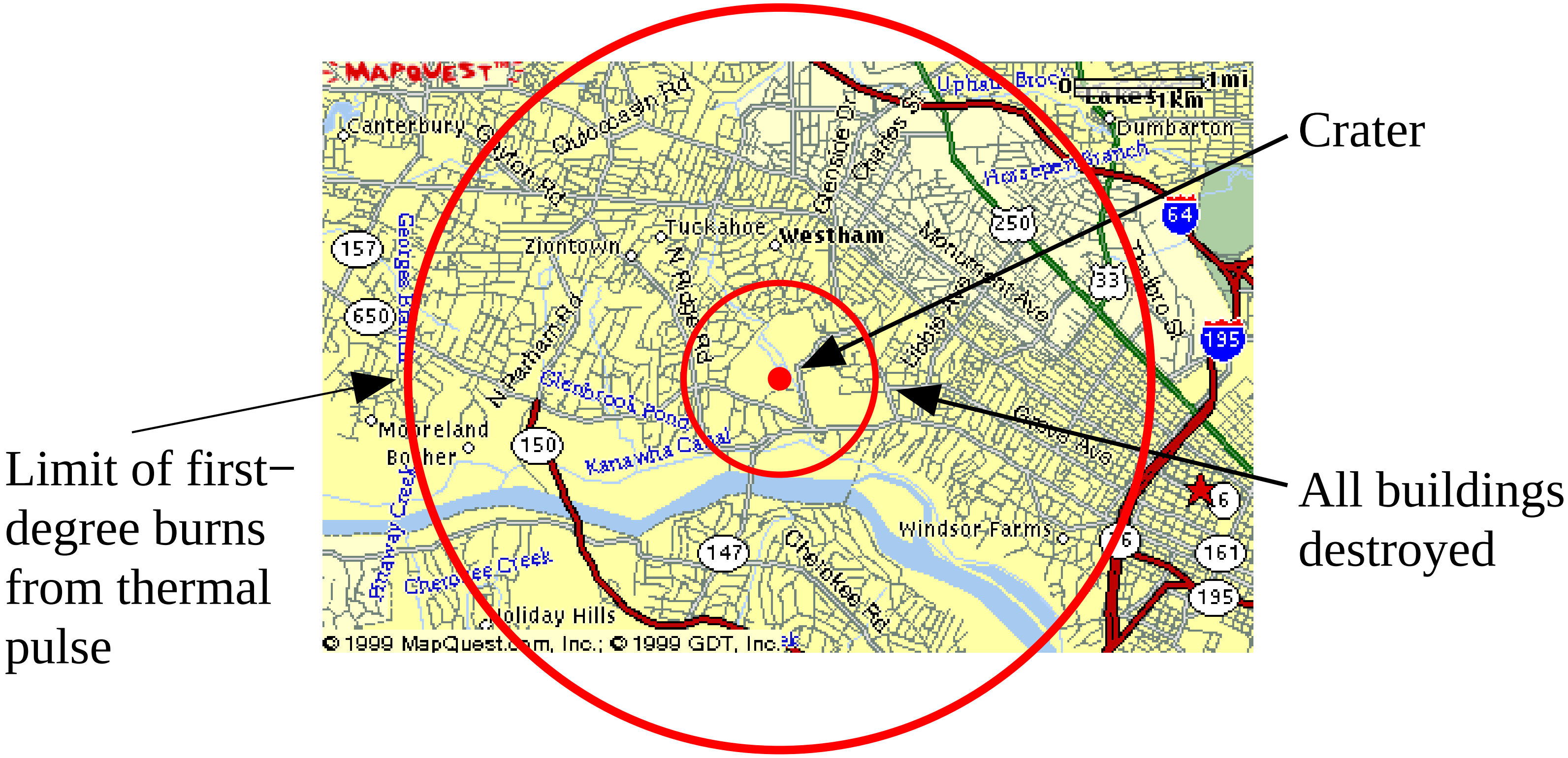
- High explosive detonates crushing the plutonium pit to a density where the fission neutrons will usually strike another nucleus instead of escaping.

- The energy released by the primary crushes the uranium tamper, the fusion fuel (containing deuterium and ^6Li), and the remaining plutonium. The uranium and plutonium ‘burn’ and increase the temperature until fusion occurs.

- The energy released by the fusion reaction raises the temperature even higher and burning more of the fission fuel.

Nuclear Weapons 101

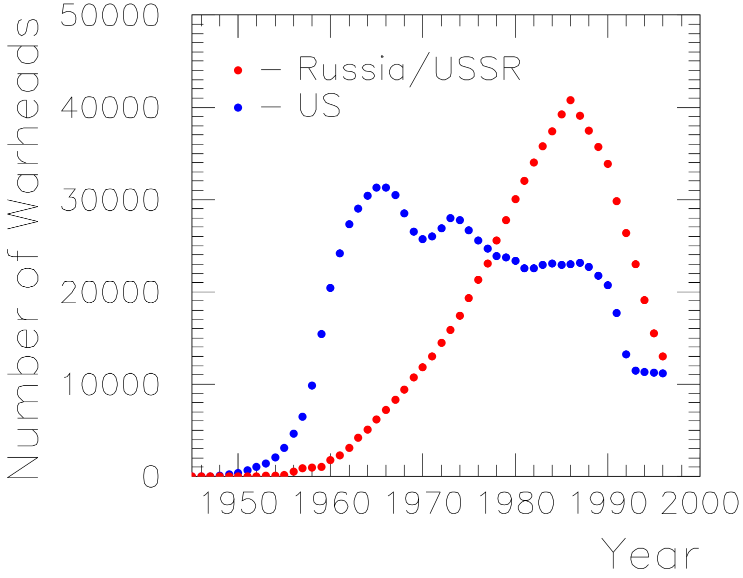
- A nuclear explosion releases huge amounts of energy. The picture below illustrates the effect of a 20 kiloton blast (about the size of the bomb used at Nagasaki) dropped on the Gottwald Science Center.



- The energy is emitted as heat, radiation, and blast. The red dot in the center is the size of the crater. The first red circle is the limit where essentially all buildings will be destroyed. The outer circle is the limit where the heat and radiation will cause first-degree burns.

Fissile Material Security in Russia

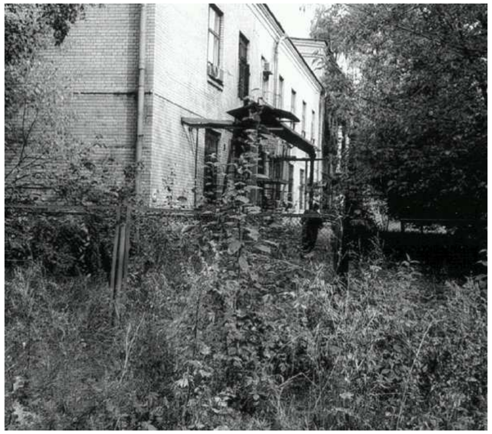
- By the end of the Cold War the US and USSR had nuclear arsenals containing about 64,000 warheads on various delivery vehicles.
- US and Soviet military stockpiles contained about 1600 tons of highly-enriched uranium (HEU) and about 200 tons of plutonium.



- An unforeseen consequence of the end of the Cold War was the disposition of nuclear weapons materials.

Fissile Material Security in Russia Declines

- The economic situation in Russia left few funds for maintaining the security of now-unused nuclear materials.
- Reports by the National Research Council in 1994, 1997 and 1999 have revealed the extent of the decline of security.



Building at the Kurchatov Institute housing enough HEU for a nuclear bomb. It had no motion sensors, detectors, or portal monitors.

- In the 1990's there have been numerous instances of smugglers apprehended with nuclear materials.
- In late 1998 the Russian FSB (successor to the KGB) reports stopping an attempt to steal 18.5 kg of weapons-usable material.

Why should you care?

- The US and most other nations have a long-standing policy of nuclear nonproliferation.
- A nuclear blast would have horrific consequences; loss of life, property, and security.
- Even acquisition of a nuclear weapon by an adversary could have a devastating influence on US security and non-proliferation.
- **One of the highest hurdles to obtaining a nuclear weapon is acquiring enough weapons-grade fissile material to produce a bomb**. Iraq spent \$5-\$10 billion in the 1980's to produce a few grams of plutonium.
- Smuggling fissile material is a 'short-cut' to acquiring nuclear weapons; it lowers the acquisition hurdle.
- Prevention (*i.e.*, security) is critical especially against an 'insider' threat.

The US Response

- In 1991 the US Congress passes the Nunn-Lugar Act. The US would pay to improve security of fissile materials and to dismantle the Russian nuclear complex (cooperative threat reduction).

Fissile Material Storage Facility under construction at Mayak, financed by the US Cooperative Threat Reduction program.

- The US spends about $400 million a year to improve material security and accounting, pay scientists, destroy missiles and submarines, and increase export controls.
- Despite this expenditure, the problem remains large[1].
- Are there new technologies that can enhance fissile material security?

[1] National Research Council, *Protecting Nuclear Weapons Materials in Russia*, (Washington, DC: National Academy Press, 1999).

What is the threat?

- Vulnerability of fissile material to insider theft.
  - The USSR relied on ‘guards, guns, and gulag’ for security. Morale in the defense complex was high and there was less concern about smuggling by the staff.
  - Financial and economic problems in the Russian nuclear cities during the 1990’s made the staff susceptible to the temptation of nuclear smuggling.
- Are there buyers?
  - Maybe!
  - Iraq spent $5-$10 billion in the 1980’s to produce a few grams of plutonium. They continue this effort.
  - Iran has been acquiring nuclear technology (some from the Russians) for many years.
  - Aum Shinrikyo and Osama bin Laden’s group (two terrorist organizations) supposedly tried to obtain fissile material.

Other Projects and Lessons Learned

- Other things I did.
  - Net Assessment of the Comprehensive Test Ban Treaty.
  - Investigating the future of cooperative threat reduction.
  - Assessing preventive threat reduction.
  - Science and technology review of DTRA R&D.
- Lessons learned.
  - Government is in dire need of technical and scientific expertise.
  - The research tends to be broader than traditional physics research, but is not as 'deep' (don't take this to mean it's lower quality, easier, less important, *etc*).
  - The work and the issues you confront are important.
  - Uses your physics training to contribute to improving society.