Physics/Global Studies 280

Module 8: Nuclear Arms Control

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Nuclear Arms Control Topics

- Nature and goals of arms control
- The nature of treaties
- Overview of nuclear arms control treaties
- Nuclear arms control during the Cold War
- Nuclear arms control in the post-Cold War era
- Nuclear arms control in the unilateralist U.S. era
- Verification of nuclear arms control treaties
- Nuclear Safeguards

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Nuclear Arms Control

Nature and Goals of Arms Control

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Understanding Arms Control

Arms Control is one tool in the toolbox of international relations (laws and norms), which also includes

- Diplomacy
  - Bilateral
  - Multilateral (including the United Nations)
- Military Force
  - Self defense
  - If all else fails and action is justifiable (morality)
- Other security instruments
  - Political
  - Economic
  - Technological
  - Environmental

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Understanding Arms Control

Arms Control is not the antithesis of military power.

- It was often portrayed as that during the Cold War
- It is the same as disarmament
- It is not the answer to all problems

Arms Control is imperfect.

- So also is diplomacy and the use of military force
- The right questions to ask are, “Is there a better way? A cheaper way? A more effective way? A less risky way?”

Understanding Arms Control

Unilateral reciprocal steps without treaties are possible but rarely successful in the long run.

Treaties have been more successful.

Arms control is not a unilateral act —

- Two or more parties (usually states) are involved
- An agreement is possible *only* if all the parties involved see it as in *their* best interests
- If conditions change, interests can change and one or more parties may view an earlier agreement as no longer in their best interest

Goals of Nuclear Arms Control

There are many possible motivations for controlling nuclear arms:

- Reduce the risk of nuclear war
- Avoid the use of nuclear weapons
- Eliminate the threat of nuclear weapons
- Reduce the cost of a nuclear arms race
- Enhance international security and stability
- Facilitate international cooperation

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Nuclear Arms Control

Most nuclear arms control is about preventing and reversing or, at least, slowing nuclear proliferation, i.e., the spread of nuclear weapons and nuclear weapons capability

- Horizontal proliferation: the spread of NWs to additional states (or non-state actors)
- Vertical proliferation: the increase in the number and/or capability of the NWs of states that already have them
- Vertical and horizontal proliferation are inherently coupled
- The ultimate motivation for pursuing nuclear arms control is that NWs threaten the very existence of humanity, as well as individual nations and human civilization

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Nuclear Arms Control

Overview of Nuclear Arms Control Treaties

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Key Nuclear Arms Control Agreements and Year Signed (Important)

- 1963 Limited Test Ban Treaty (LTBT)
- 1968 Nuclear Nonproliferation Treaty (NPT)
- 1972 Strategic Arms LimitationTreaty (SALT) =
  Ant-Ballistic Missile Treaty (ABMT)
  + Interim Agreement on Offensive Forces
- 1974/1980 Threshold Test Ban Treaty (TTBT)
  + Peaceful Nuclear Explosions Treaty (PNET)
- 1987 Intermediate-Range Nuclear Forces Treaty (INFT)
- 1991 Strategic Arms Reduction Treaty (START)
  + 1992 Lisbon Protocol regarding successor states
- 1996 Comprehensive Test Ban Treaty (CTBT), not yet in force
- 2002 Strategic Offensive Reductions Treaty (SORT)
- 2011 New START

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Other Important Nuclear Arms Control Agreements and Year Signed

- 1959 Antarctic NWFZ Treaty
- 1967 Latin America Nuclear-Weapons-Free Zone Treaty (Tlatelolco)
- 1968 African NWFZ Treaty (Treaty of Pelindaba)
- 1970 Outer Space Treaty
- 1971 Seabed Treaty
- 1979 Strategic Arms LimitationTreaty II (SALT II), never ratified
- 1985 South Pacific NWFZ Treaty (Treaty of Rarotonga)
- 1987/1993 Missile Technology Control Regime (MTCR)
- 1994 Agreed Framework between US and DPRK
- 1995 South-East Asian NWFZ Treaty (Treaty of Bangkok)
- 1997 Strategic Arms Reduction Treaty II (START II), never ratified
- 2002 International Code of Conduct against Ballistic Missile Proliferation (ICOC)

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History of Strategic Nuclear Arms Agreements

- 1972 : Nixon — Strategic Arms Limitation Treaty (SALT) and Anti-Ballistic Missile Treaty (ABMT), approved
- *1979 : Carter — Second Strategic Arms Limitation Treaty (SALT II), withdrawn*
- 1987 : Reagan — Intermediate-Range Nuclear Forces Treaty (INF), approved
- 1991: Reagan & Bush I — Strategic Arms Reduction Treaty (START I), approved
- 1992 : Bush I — Lisbon Accord, approved
- *1993 : Bush I & Clinton — Strategic Arms Reduction Treaty II (START II), Senate did not consent*
- *1996 : Clinton — Comprehensive Test Ban Treaty (CTBT), Senate did not consent*
- 2002 : Bush II — Strategic Offensive Reductions Treaty (SORT), approved
- 2010 : Obama — New Strategic Arms Reduction Treaty (New START), approved

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Nuclear Arms Control

The Nature of Treaties

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The Nature of Treaties

- A treaty is a written agreement between two or more sovereign states in which the parties involved agree to abide by certain specified procedures and standards of conduct
- The Vienna Convention on the Law of Treaties (opened for signature 1969, entered into force 1980) sets the rules for treaties in international law.

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The Nature of Treaties

- Signature: Signature by an authorized State representative (*need not be the highest official*).
- Ratification: Each of the participating parties go through a domestic "ratification" process that is designed to show that the state agrees to be bound by the treaty, independent of future changes in political leadership.
- Entry into Force: The treaty specifies the conditions for its entry into force, typically based on the number of ratifying states.

  Default: Ratification by all negotiating states.

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The Nature of Treaties

Member State Status

- During negotiations: Negotiating State
- After signature: State Signatory
- After ratification: Ratifying State
- After entry into Force: State Party

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The Nature of Treaties

Obligations prior to entry into force and for withdrawal —

- According to the Vienna Convention on the Law of Treaties, a state that has signed a treaty is bound to it and is obliged to refrain from acts which would defeat the object and purpose of a treaty even if it has not yet ratified the treaty.
- A state can change its mind before ratification. After announcing to the world that it is withdrawing its signature, it is no longer bound.
- After ratification, a state is obligated to announce to the world in advance that it plans to withdraw from a treaty.
  - —The treaty specifies the advanced notice required.
  - —In arms control treaties this is referred to as the "Supreme National Interest" clause.

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The Nature of Treaties

Traditionally, treaties are "deposited" at one or more locations (depository) where they may be studied by any interested party

- It is rare to have "secret" treaties or secret parts of treaties in the arms control context
- International knowledge and support is usually one of the reasons states enter into treaties

The Vienna Convention on the Law of Treaties clarifies a wide range of issues associates with treaties of all types

- Interpretation of language
- Norms of conduct not explicitly prescribed in the treaty
- Traditional practice (common sense) also applies

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The Nature of Treaties

A written agreement does *not* have to have the word “treaty” in its title to be a treaty

- What is required are the features described above
- The word “Convention” is a common substitute for the word “Treaty” in titles, but taken alone “Convention” does not itself imply the agreement is a treaty
- Examples: Biological Weapons Convention, Chemical Weapons Convention
- The word “Protocol” is used in many different ways in the international context
  - — to describe a treaty in itself
  - — to describe a part of or an amendment to a treaty
  - — to describe something less than a treaty (analogous to “laws” in physics)

An “Executive Agreement” is an agreement between the heads of two (or more) states and is not binding on future heads of state (and therefore is much less binding than a treaty)

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The Nature of Treaties

A treaty typically has an “official” name and a “familiar” name (a nickname), which often includes the geographical location where it was negotiated or signed

The number of parties to treaties can vary

- Distinguish “bilateral”, “trilateral” and “multilateral” treaties
- Goal for “universal” treaties

The duration of treaties can vary

- “Indefinite duration” means forever (for all time)
- A treaty can also be for only a specified duration

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Nuclear Arms Control

Nuclear Arms Control During the Cold War

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First Success: The 1963 Limited Test Ban Treaty

- Was agreed by the U.S. and Soviet Union in 1963
- Considerations started in 1954, originally aiming at a comprehensive test ban treaty
- Built on 8 years of work beginning with the Eisenhower administration
- Was negotiated by Averill Harriman, Kennedy's special ambassador, in face-to-face negotiations with Nikita Khrushchev in only 10 days in July–August 1963
- Was signed Aug. 5, 1963, ratified by the U.S. Senate on Sep. 24, 1963, entered into force Oct. 10, 1963. Record Time!
- US, USSR, and UK were the original parties
- Almost all states of the world are now parties to the LTBT

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The 1963 Limited Test Ban Treaty

Provisions —

- A two-page treaty (see the Ph280 documents web page)
- Bans “any nuclear weapons test explosion, or any other nuclear explosion”
- “in the atmosphere; beyond its limits, including outer space; or underwater”
- “in any other environment if such explosion causes radioactive debris to be present outside the territorial limits of the State...”
- Has no verification provisions: verification is easy using existing surveillance technologies because of the unique signatures of a nuclear explosion

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The 1963 Limited Test Ban Treaty

- Came about largely as a response to world-wide public outcry against fallout from atmospheric testing
- Role of scientists (Nobel Peace Prize Linus Pauling)
- Original goal eliminating all nuclear testing failed because of internal political opposition within the three countries and because of controversy over whether underground tests could be detected (this question was again used by U.S. opponents of the CTBT as an excuse not to ratify it)
- Was the first sign of hope for controlling nuclear weapons, but in practice was primarily an environmental protection measure (radioactivity from nuclear testing restricted to the underground

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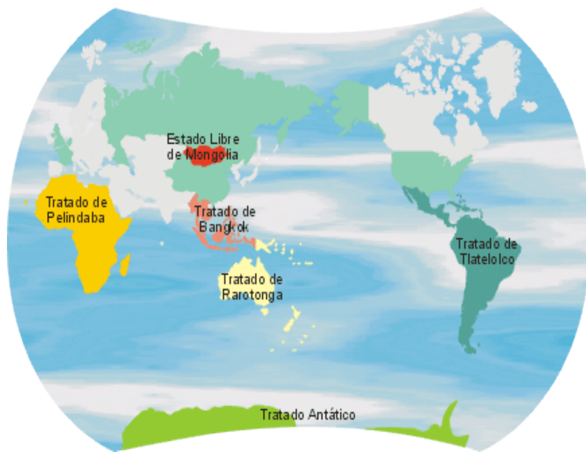
Nuclear-Weapon-Free Zones

- NWFZs are in force on the territory of 110 countries
- Some are single-state NWFZs (Austria, Mongolia)
- In preparation: Central Asian Nuclear-Weapon-Free Zone
- Almost the whole southern hemisphere is covered by NWFZs

Question — Why is there no Nuclear-Weapon-Free Zone in Northeast Asia or the Middle East?



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Other “Nuclear Free Zones”

- 1967 Outer Space Treaty
  - —No basing of NWs in orbit about earth
  - —Moon and other celestial bodies (planets, asteroids, etc.) nuclear free zones
  - —Numerous other restriction on state behavior that are unrelated to nuclear weapons
- 1971 Seabed Treaty
  - —No basing, storage, of testing of NW (or other WMD) on seabed, ocean floor, and subsoil thereof
  - —Does not apply to coastal waters (12 mile limit)
  - —Modeled after Outer Space Treaty

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Physics 280: Session 27

Student questions

News and discussion

Module 8: Nuclear Arms Control (cont'd)

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News and Discussion

Global Security Newswire
by National Journal Group

Daily news on nuclear, biological and chemical weapons, terrorism and related issues.

Iran Reports New Computer Strike

Monday, April 25, 2011

Iran is facing a new computer-based attack by hostile powers, a high-level Iranian military officer told the nation's Mehr News Agency on Monday (see ***GSN***, April 22).

Specialists are investigating the malware, dubbed "Stars," Reuters quoted Gholam Reza Jalali, who heads the Iranian armed forces' Passive Defense branch, as saying.

The Stuxnet worm also remains a threat, the official added (see ***GSN***, April 18). "We should know that fighting the Stuxnet virus does not mean the threat has been completely tackled, because viruses have a certain life span and they might continue their activities in another way," he said.

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News and Discussion

U.S.-Russia Defense Technology Pact in the Works

Monday, April 25, 2011

By Martin Matishak
Global Security Newswire

WASHINGTON -- The United States is working to revive an agreement with Russia that would serve as the legal foundation for the two nations to exchange potentially sensitive information on a broad range of technologies, including missile defense systems (see ***GSN***, April 22).

The Defense Technology Cooperation Agreement is a bilateral contract that would provide a legal framework on a host of defense-related research and development activities, including measures for countering improvised explosive devices, a senior Defense Department official told *Global Security Newswire.*

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News and Discussion

Donilon Op-Ed Courts Support for Nuclear Weapons Reduction

Tuesday, April 19, 2011

By Rebecca Kaplan
National Journal

WASHINGTON -- Against the backdrop of implementation of the New START treaty with Russia, national security adviser Tom Donilon took to the pages of the ***Financial Times*** to outline the administration's plans for nuclear weapons reduction in the future (see ***GSN***, April 11).

The plans are grand. Donilon calls for further reduction of the role and number of U.S. tactical nuclear weapons (done along with Russia), the use of an international fuel bank to prevent the proliferation of nuclear energy, and bringing the Comprehensive Test Ban Treaty into force while seeking to ban production of fissile material for nuclear weapons (see ***GSN***, April 14). The latter two goals will require approval by the Senate, which Donilon courts by saying it serves U.S. interests by limiting nuclear buildup in Asia. "Significant political hurdles must be overcome to make progress on these last two aims," he acknowledges (see ***GSN***, March 29).

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News and Discussion

North Korea Using Front Companies For Nuke Program, U.N. Panel Finds

Wednesday, April 20, 2011

North Korea is employing foreign missions and front firms to illegally sell and acquire missile- and nuclear-associated technology, according to a January U.N. Panel of Experts report (see ***GSN***, April 19).

The report, detailed by Kyodo News, also concludes that the Stalinist state's proclaimed uranium enrichment program seems to be "primarily for military reasons or at least for dual use," reported the *Chosun Ilbo*.

"If the Yongbyon uranium enrichment facility is operated to produce highly enriched uranium, it could make 25-33 [kilograms] of it, which would be sufficient for making one to two nuclear bombs per year," the report states.

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News and Discussion

Meanwhile, a senior military officer on Wednesday said the U.S. command in South Korea was "very closely" tracking North Korean armed forces activities, the Yonhap News Agency reported

"We observe forces in North Korea very closely in conjunction with intelligence capabilities of the [South Korean] military," Lt. Gen. John Johnson said to journalists.

On Tuesday, the head of South Korea's intelligence service said the North might conduct a third nuclear test if it failed to re-establish talks with nations participating in the six-party process. The multinational negotiations on North Korean denuclearization -- which involve China, Japan, Russia, the United States and both Koreas -- have not been held since December 2008.

The U.S. military has not seen indications of an imminent nuclear or missile test, Johnson said.

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iClicker Question

Roughly speaking, President Obama’s proposed U.S.-based midcourse intercept defense program

A. Cancels President Bush’s program

B. Continues President Bush’s program

C. Accelerates President Bush’s program

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iClicker Answer

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iClicker Question

President Bush's European-based missile defense program was supposed to have become operational in what year?

A. 2010

B. 2012

C. 2014

D. 2016

E. 2018

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iClicker Answer

President Bush's European-based missile defense program was supposed to have become operational in what year?

A. 2010

B. 2012

C. 2014

D. 2016

E. 2018

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iClicker Question

The first phase of President Obama's European-based missile defense program is supposed to become operational in what year?

A. 2010

B. 2011

C. 2012

D. 2015

E. 2018

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iClicker Answer

The first phase of President Obama's European-based missile defense program is supposed to become operational in what year?

A. 2010

B. 2011

C. 2012

D. 2015

E. 2018

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iClicker Question

The second phase of President Obama's European-based missile defense program is supposed to become operational in what year?

A. 2010

B. 2011

C. 2012

D. 2015

E. 2018

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iClicker Answer

The second phase of President Obama's European-based missile defense program is supposed to become operational in what year?

A. 2010

B. 2011

C. 2012

D. 2015

E. 2018

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Horizontal Nuclear Non-Proliferation

1955: Atoms for Peace

1957: International Atomic Energy Agency (IAEA) formed

Verification: Nuclear Safeguards

- The initial safeguards agreement did not provide full-scope safeguards
- Full-scope safeguards came after the 1968 NPT (in the Model Safeguards Agreement of 1971)

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The 1968 Nuclear Non-Proliferation Treaty

- Signed in 1968 (Johnson Administration), went into force in 1970, had 25-year term
- Renewed for an *indefinite* term in May 1995
- State Parties meet every 5 years to review effectiveness of treaty & propose improvements of implementation
- **Divides states of the world into two classes**
  - **Nuclear Weapons States (NWS)** ***defined*** **by treaty as states that have tested before 1968: US, USSR/R, UK, Fr, PRC only**
  - **Non-Nuclear Weapons States (NNWS)**
- **Grand bargain**
  - **NWs states agree to share peaceful applications of nuclear technologies with NNS**
  - **NNW states agree not to develop or acquire NWs**
- De-facto NWS Israel, India, Pakistan, and North Korea are the only non-signatories
- Inclusion of Israel, India, Pakistan, and North Korea as NPT NWS would require amending the treaty, which would be tantamount to re-negotiating it; such a

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The 1968 Nuclear Non-Proliferation Treaty

Iraq, Libya, Iran, and N. Korea were/are problematic signatories

- Post Iraq War searches provided definitive assurance that the Iraqi NW program is eliminated
- Libya ended nuclear weapons program
- North Korea withdrew from the NPT, launched a NW program (U enrichment and Pu reprocessing), declared possession of nuclear weapons in March 2005 and tested them in October 2006
- Iran is a complicated case of different dimensions

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The 1968 Nuclear Non-Proliferation Treaty

The 1995 NPT Review and Extension Conference agreed on a document called “Principles and Objectives on Nuclear Non-Proliferation and Disarmament”

The 2000 NPT Five-Year Review produced an agreed list of the most relevant next steps (13 steps)

The 2005 NPT Five-Year Review was very troubled

The 2010 NPT Five-Year Review was more successful

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The NPT Additional Protocol

- IAEA safeguards system: aims to detect and deter diversion of nuclear materials used for civilian purposes to materials used to make weapons.
- IAEA currently monitors more than 800 facilities in more than 100 nations.
- Iraq case 1991
- Loophole of nuclear safeguards: inability by design to detect clandestine nuclear activities
- 93+2 program to enhance efficiency and effectiveness of nuclear safeguards
- Model Additional Protocol (INFCIRC-540) in 1997
- As of April 2009 signed by 90 states, in force in 65 out of 189 Parties to the NPT

Limits on SU and US Nuclear Weapons Systems

- Meaningful limitations on nuclear weapons systems proved difficult to achieve during the Cold War
- The nuclear arms race was driven by intense fear and became deeply ingrained due to many different factors
  - Competition and distrust between the two superpowers
  - Complications created by the NW programs of UK, Fr, and PRC
  - Domestic political, institutional, and economic forces, which drove the arms race in each of the NW states
  - The first limits on NW systems were achieved in 1972 as a result of the SALT (Strategic Arms Limitation Talks) negotiations during the first Nixon administration
  - Secretary of State Henry Kissinger was the architect, chief negotiator, and super salesman of the SALT-I Treaty

The Two Parts of SALT I

The first Strategic Arms Limitation Treaty (SALT-I) had two parts, one important, the other minor —

- The ABM Treaty (ABMT) was the important agreement
- The "interim agreement on offensive strategic nuclear delivery systems" (R > 5,500 km = 3,400 miles) was a minor, temporary agreement
- However, the parties could not agree on one without the other, because both parties (US and USSR) agreed that limitations on offensive nuclear delivery systems would be impossible without limitations on defensive systems
- Mutually Assured Destruction (MAD) was not in any way a policy! It was simply a fact. This fact could not be changed without getting rid of 99% or more of all nuclear weapons.

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The 1972 ABM Treaty

—Signed May 1972, ratification approved Aug 1972; in force Oct 1972

—Each party agrees not to deploy any defensive system of nationwide scope against *strategic* ballistic missiles

—Each party agrees not to develop the *basis* for a nationwide ABM system

—Two limited deployments permitted (100 interceptors)

» Defend national capital (Soviets were deploying this)

» Defend single ICBM field (US deploying this)

» Reduction to one of the above sites by a 1974 Protocol

—No prohibition on defenses against non-strategic ballistic missiles or cruise missiles

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The SALT I Interim Agreement

- Bilateral agreement; UK had ceased to be a major player, and progress would have been impossible if FR and PRC were at the table
- Established a *five-year freeze* at existing levels of *nuclear delivery systems*; those in production allowed to be deployed
- No reductions required on either side
- Parties pledge to conduct follow-on negotiations for more comprehensive measures "as soon as possible". The Interim Agreement resulted in unequal numbers in US and USSR triads---led to strong objections in US Senate.
- The opportunity to ban MIRVed ICBMs (and MIRVed SLBMs) was not considered in the negotiations which is regarded as the most serious mistake in Cold War arms control (even Kissinger agrees)
- There was long delay before a true treaty (SALT-II) on offensive system was reached in 1979 near the end of the Carter Administration.
- SALT-II was never ratified and never in force

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The SALT II Treaty

- A small step forward was made in the Ford Administration: the 1974 Vladivostok Agreement
- An agreement ("SALT-II") was completed in Carter Administration after prolonged negotiations in 1979
- Carter withdrew SALT-II from consideration by the U.S.Senate in January 1980, to avoid its rejection. Both sides pledged (a political agreement) to abide by the terms of the treaty; this lasted until 1986
- In 1986 President Reagan declared that the U.S. would no longer be constrained by the terms of the Treaty and explicitly ordered nuclear weapons to be deployed to violate the Treaty's provisions
- Basic structure:
  - —Limit of 2250 total number of SNDVs by 1981
  - —Sub-limit on number of MIRVed missiles and Heavy Bombers (HB) with cruise missiles
  - —Limit on number of warheads on ICBMs, SLBMs and HBs
  - —Numerous other sub-limits and restrictions

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The Intermediate Nuclear Forces (INF) Treaty

- Intermediate-Range Nuclear Forces (INF) Treaty was signed on December 8, 1987; entered into force in1988
- Negotiations started 1981
- Bilateral (USA-USSR) + West German unilateral declaration
- Basic structure:
  - Total global ban of a whole class of ground-based nuclear weapons
  - Applies to delivery systems with a range between 500 and 5,500 km
  - Disarmament by destruction of in total 2,695 missiles

Soviet Union:	1,836 missiles
USA:	859 missiles

  - Complete elimination within 3 years (included cruise missiles)

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The Strategic Arms Reduction Treaty (START)

- 1991 Strategic Arms Reduction Treaty Provisions
  - Negotiations began in Reagan Administration in 1982; Gorbachev was in power in the Soviet Union
  - Treaty signed in July 31, 1991 (Bush Administration)
  - Five months later Soviet Union dissolved
  - Treaty contains a of launcher (SNDV) limits and warhead limits (7 year term to reduce to)
  - WH limits expressed in terms of “accountable war heads” (AWHs)
    - » 1,600 deployed ICBMs, SLBMs and HBs
    - » 6,000 total AWHs
      - sublimit: 4,900 AWHs on ICBMs and SLBMs
      - sublimit: 1,500 on Heavy ICBMs (Soviet SS-18s)
      - sublimit: on mobile ICBMs
      - Total ballistic missile “throw-weight” limited to 3,600 metric tons

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The START Treaty (cont'd)

— Was the first treaty to require actual *reductions* of strategic nuclear forces

— Counting rules specified for each type of SNDV

» HB equipped with bombs and short-range attack missiles (SRAMs) count as 1 AWH

» HB with ALCMs count as 10, 16, or 20 AWHs

» WHs down-loaded from existing MIRVed missiles beyond 1,250 counted as "deployed"

— Treaty duration of 15 years; renewable for additional 5-year terms

— Verification by National Technical Means (NTM) plus cooperative measures

— Entry into Force: Dec 5, 1994 after the "Lisbon Protocol" was signed and ratified

— Expired in December 2009 (second Bush administration made no effort to extend it or put in place a follow-on treaty)

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Eras of Nuclear Arms Control

1989–2000: Nuclear Arms Control in the Post-Cold War Era (Bush I and Clinton)

1992 Lisbon Accord

1993 START II

1996 CTBT

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The 1992 Lisbon Protocol

Following the end of Soviet Union as political entity, something had to be done to determine who had successor state responsibility for treaties signed by USSR

- 1992 Lisbon Accord (Protocol to START-I and ABM Treaty)
  - » Russia, Belarus, Kazakhstan, Ukraine and US signatories
  - » Russian the successor nuclear weapon state under NPT
  - » Belarus, Kazakhstan and Ukraine to sign NPT as non-nuclear states (and eliminate all NW on their territories)
  - » Russian bound by START- I obligations
  - » Ukraine was the last of the newly independent states to complete all the necessary steps of nuclear disarmament

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START II

- Bush-Yeltsin signed in Moscow January 3, 1993
- SNDV ceiling of 1,600 in START-I unchanged
- Total warhead ceiling reduced to 3,000–3,500
- Actual warhead counts used (AWH unit dropped)
  - — ICBM + SLBM WH ceiling dropped
  - — MIRVed ICBMs completely forbidden
  - — All Heavy ICBM (SS-18s) eliminated
  - — SLBM WH ceiling of 1,700–1,750 added
  - — Mobile ICBM WH ceiling of START-I left at 850
- Warheads downloaded from MIRVed missiles may not be restored
- To remain in force as long as START is in force (December 2009)

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START II (cont'd)

- US agreed to help Russians with destruction costs and technologies
- Entry into force in two phases with initial dates
  - — Phase1 complete 7 years after START signed
  - — Phase 2 complete in 2003
  - — Phase 2 deadline later extended to 2007
- Ratified by US in 1996, but US did not ratify 1997 protocol extending implementation, ABM Treaty succession, and agreement clarifying demarcation line between strategic and theater ballistic missile defenses
- Russian ratification subject to the provision that the US remain bound by the ABM Treaty
- US refusal to make that commitment

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START III Talks

- During period 1993–2000 when START II was signed but not in force, major changes were taking place in Russia
- Russia repeatedly expressed interest in WH limits lower than START II limits
- Limit of 2,000- 2,500 WH informally agreed between Clinton and Yeltsin
- Russians proposed limits of 1,500 WH
- Some on US side proposed 1,000 WHs (minimum deterrence)
- Verifiable destruction of WHs to be included
- Other transparency measures explored
- Never any formal negotiations
- Lost opportunity of a decade?

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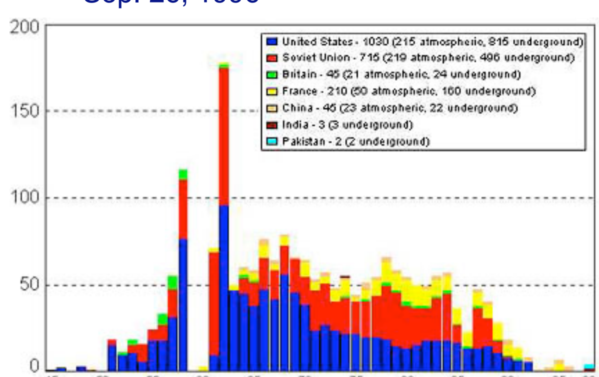
CTBTO PREPARATORY COMMISSION | preparatory commission for the comprehensive nuclear-test-ban treaty organization

Comprehensive Nuclear Test Ban Treaty

- Negotiated 1993–1996 at the CD in Geneva
- Opened for signature in September 1996 in New York
- As of April 2010: 180 signatories, 148 ratifications. Of the 44 in Annex II, 9 have not ratified. They are: China, Egypt, India, Indonesia, Iran, Israel, North Korea, Pakistan, and the United States
- UN General Assembly Resolution in November 1996 created the Preparatory Commission with its Provisional Technical Secretariat in Vienna.
- The International Monitoring System with 321 stations worldwide is under construction. It comprises of seismic, hydroacoustic, infrasound and radionuclide sensors.

History of Test Ban Treaties

	Signature	Entry into Force
• Partial TBT	Aug. 5, 1963	Oct. 10, 1963
• Threshold TBT	July 3, 1974	Dec. 1, 1990
• Peaceful Nuclear Explosions Treaty	May 28, 1976	Dec. 11, 1990
• Comprehensive TBT	Sep. 26, 1996	—



Nuclear Arms Control Eras

2001–2009: Nuclear Arms Control in the Unilateralist U.S. Era (Bush II)

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A New Approach to Nuclear Weapons

- Bush II Administration took a new approach toward limiting strategic nuclear forces
  - —Abandoned the ABM Treaty as not in US interests
  - —Abandoned the START II Treaty
  - —Declared formal treaties unnecessary and undesirable, because they would restrict US freedom of action
  - —Expressed desire for friendly relations with Russia
- The Treaty on Strategic Offensive Reductions (SORT) was the first and only product of this new approach
  - —Putin insisted that the agreement be a formal treaty and the United States yielded on this point!

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Strategic Offensive Reductions

SORT was signed in Moscow in May 2002

- It reduce total number of strategic nuclear warheads to 1,700 – 2,200 by Dec 31, 2012
- It will expire Dec 31, 2012 (but can be extended)
  - —No sub-limits or other conditions
  - —No schedule for reductions
  - —de-MIRVing and/or WH destruction not required
  - —Non-deployed WHs not counted
  - —START-I remains in force
- Parties can withdraw three months after giving notice
- Entered into force in 2003; superseded by New START

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Physics 280: Session 28

Final Exam Review Session

Sunday, May 8th, at 7:30 PM in144 Loomis

Plan for This Session

Student questions

Schedule Final Exam Review Session

Module 8: Nuclear Arms Control

Next: “Countdown to Zero” Video

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Nuclear Arms Control Eras

2009–present: Nuclear Arms Control in the Present Era (Obama)

Frederick K. Lamb © 2011

News and Discussion

Global Security Newswire by National Journal Group

Daily news on nuclear, biological and chemical weapons, terrorism and related issues.

Obama Inks New START Ratification Text

Wednesday, Feb. 2, 2011

Frederick K. Lamb © 2011

Current Nuclear Arms Control Priorities of the Obama Administration

- A treaty to reduce the number of tactical nuclear weapons
- An internationally-controlled "nuclear fuel bank" for reactor fuel
- Ratification and entry into force of the Comprehensive Test Ban Treaty (CTBT)
- A treaty to end the further production of fissile material

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The Dangers of Nuclear Proliferation

- Governments unfriendly to the U.S. are increasingly trading with one another to obtain nuclear weapons
- Nuclear weapon materials and technology are increasingly being proliferated by private networks, like the A.Q. Khan network based in Pakistan
- Theft, diversion, and sale of nuclear materials and technologies increases the danger of nuclear terrorism

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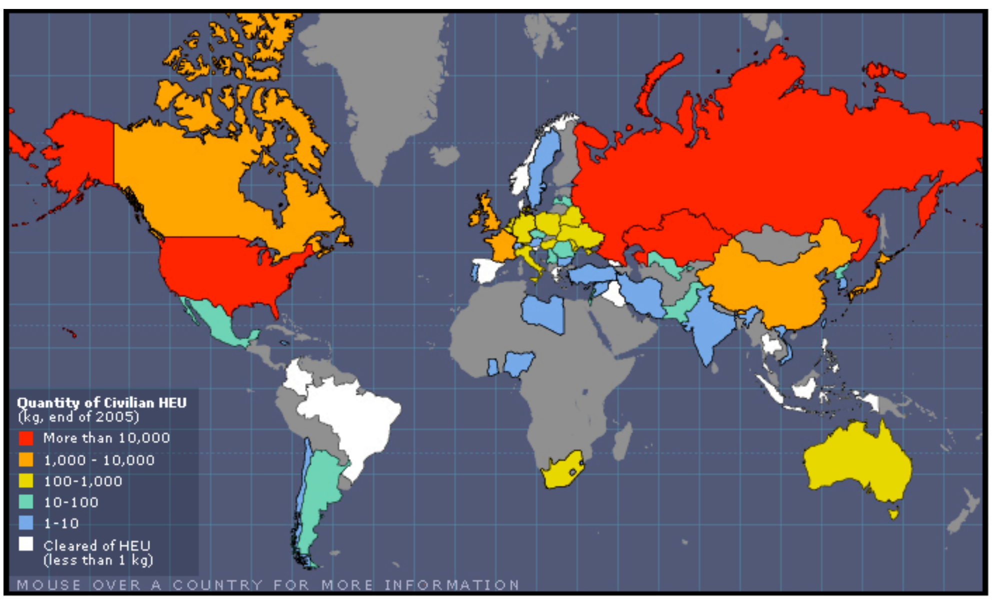
Availability of Uranium from “Atoms for Peace”

Atoms for Peace

- During the 1950s and 1960s, the U.S. Atoms for Peace program and the corresponding Soviet program constructed hundreds of research reactors, including reactors for export to more than 40 other countries.
- These reactors were originally supplied with low-enriched Uranium (LEU), which is not usable for nuclear weapons, but demands for better reactor performance and longer-lived fuel led to a switch to weapons-grade Highly Enriched Uranium (HEU).

Availability of Highly Enriched Uranium
Effect of “Atoms for Peace”



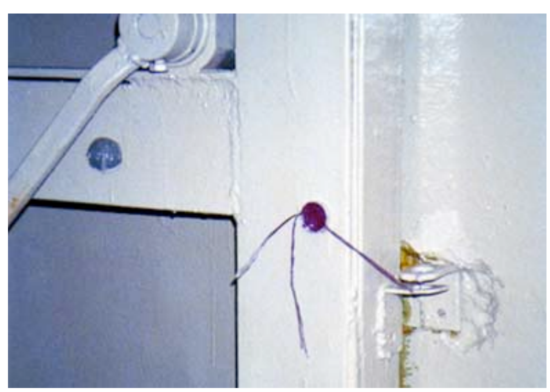
Availability of Nuclear Weapon Materials in the Former Soviet Union

As of 1994, Building 116 at the Kurchatov Institute in Moscow had enough HEU for a bomb at its research reactor, but had an overgrown fence and no intrusion detectors or alarms, an example of the poor state of security at many nuclear facilities after the collapse of the Soviet Union.
Source: http://www.nti.org/e_research/cnwm/threat/russia.asp

Frederick K. Lamb © 2011

Availability of Nuclear Weapon Materials in the Former Soviet Union

Left and below: Inadequate security measures at former Soviet nuclear facilities, such as the padlock and wax seal shown, would allow easy access to anyone wishing to steal materials.



Source: http://www.nti.org/e_research/cnwm/threat/russia.asp

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Delivery Methods Other Than Long-Range Ballistic Missiles Pose Greater Threats

Several countries are capable of developing mechanisms to launch SRBMs, MRBMs, or land-attack cruise missiles from forward-based ships or other platforms. Some may develop such systems before 2015.

U.S. territory is more likely to be attacked with [nuclear weapons] using non-missile delivery means—most likely from terrorists—than by missiles, primarily because non-missile delivery means are —

- less costly
- easier to acquire
- more reliable and accurate

They also can be used without attribution.

— Unclassified summaries of the most recent National Intelligence Estimates of Foreign Missile Developments and the Ballistic Missile Threat Through 2015

 Frederick K. Lamb © 2011

iClicker Question

Roughly speaking, President Obama's proposed U.S.-based midcourse intercept defense program

A. Cancels President Bush's program

B. Continues President Bush's program

C. Accelerates President Bush's program

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Blank

Frederick K. Lamb © 2011

iClicker Answer

Roughly speaking, President Obama's proposed U.S.-based midcourse intercept defense program

A. Cancels President Bush's program

B. Continues President Bush's program

C. Accelerates President Bush's program

Frederick K. Lamb © 2011

iClicker Question

President Bush’s European-based missile defense program was supposed to have become operational in what year?

A. 2010

B. 2012

C. 2014

D. 2016

E. 2018

Frederick K. Lamb © 2011

Blank

Frederick K. Lamb © 2011

iClicker Answer

President Bush's European-based missile defense program was supposed to have become operational in what year?

A. 2010

B. 2012

C. 2014

D. 2016

E. 2018

Frederick K. Lamb © 2011

iClicker Question

The first phase of President Obama's European-based missile defense program is supposed to become operational in what year?

A. 2010

B. 2011

C. 2012

D. 2015

E. 2018

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Blank

 Frederick K. Lamb © 2011

iClicker Answer

The first phase of President Obama's European-based missile defense program is supposed to become operational in what year?

A. 2010

B. 2011

C. 2012

D. 2015

E. 2018

 Frederick K. Lamb © 2011

iClicker Question

The second phase of President Obama's European-based missile defense program is supposed to become operational in what year?

A. 2010

B. 2011

C. 2012

D. 2015

E. 2018

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Blank

Frederick K. Lamb © 2011

iClicker Answer

The second phase of President Obama's European-based missile defense program is supposed to become operational in what year?

A. 2010

B. 2011

C. 2012

D. 2015

E. 2018

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Nuclear Arms Control Treaties

Monitoring Nuclear Arms Control Treaties

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Functions of Verification

- It allows the parties to **assess an agreement's state of implementation**. By establishing how each party is fulfilling its obligations, verification gives a good indication about the functioning of the agreement.
- It **discourages non-compliance** with agreement provisions. Because parties know that breeches of obligations carry the risk of detection, they should be less inclined to attempt to renege secretly on their commitments.
- It provides **timely warning of violation(s)** of agreement conditions. In case of non-compliance, verification can reveal transgressions before these have a chance to turn alarming.
- By checking that obligations are indeed being honored, it helps **generate confidence** that the agreement and its verification mechanism are functioning as intended, thereby fostering trust and confidence between the parties.

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Verification Means and Procedures

1. Monitoring technologies

•Remote sensors in the visible, infra-red or radar spectra, based on satellites, aircraft or on the ground

•Signal and electronic reconnaissance

•Seismological, radionuclide, hydroacoustic and infrasound monitoring

•On-site sensors for non-destructive measurement, e.g. portal perimeter monitoring; measurement of weight, length, acoustics, light (UV, infrared, visible), electrical and magnetic fields; passive radiation measurement, active radiation (x-ray, gamma ray, beta particles, protons, neutrons)

2. Verification methods

•International Agency for Verification

•Cooperative fact finding on compliance

•Consultation

•Dispute settlement

3. Cooperative procedures

•Nuclear archaeology

•Initial declarations and data exchange

•Identification & item counting of objects (tagging, fingerprinting, registration,

•Confidence-building measures

•Joint overflights (Open Skies)

•Accountancy, control and surveillance

•Preventive controls at nuclear facilities

•Baseline and routine inspections

•Challenge inspections of suspected facilities (anytime-anywhere)

•Personal observation of destruction and suspected activities

4. Societal verification

•Open sources, scientific knowledge

•Citizen reporting, protect whistle-blowing

•Espionage

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Introduction to Nuclear Safeguards

What are Nuclear Safeguards?

"…the objective of safeguards is the timely detection of diversion of significant quantities of nuclear material from peaceful nuclear activities to the manufacture of nuclear weapons or of other nuclear explosive devices or for purposes unknown, and deterrence of such diversion by the risk of early detection." - *IAEA, INFCIRC 153*

A method by which a state or an international organization prevents or detects the theft or misuse of nuclear material by an adversary.

- An adversary can be an individual, a sub-state group or – in the case of an international organization – a state.

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Introduction to Nuclear Safeguards (cont'd)

•Although a state will use safeguards for its own domestic nuclear program, this module will focus primarily on safeguards through the scope of the International Atomic Energy Agency (IAEA).

•When the IAEA enters a safeguards agreement with a state and places safeguards at that state's facilities, the IAEA must treat the state as a potential adversary. This brings up several challenges:

- The IAEA must be able to perform it's mission to detect SQ within the specified timely manner.
- But IAEA safeguards cannot hinder or inconvenience the regular operation of the nuclear facility.
- The state can unilaterally modify or expel IAEA safeguards (ex: North Korea).

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Safeguards Agreements

- IAEA safeguards agreements are separated by two general categories:
  - weapons states (WS) as described by the NPT.
  - non-weapons states (NWS)
- WS agreements are generally less stringent than those with NWS and exist mostly on "good faith". (There is little need to prevent a WS from diverting material to build weapons.)
- Issues between NWS under safeguards and the IAEA may be referred to the UN Security Council. Such issues may include:
  - Noncompliance with agreements
  - Detection of non-declared activities
  - Detection of a large amount of missing nuclear material.

Constraining Horizontal Nonproliferation

The International Atomic Energy Agency (IAEA) and the Non-Proliferation Treaty (NPT) —

The Agency's Safeguards (INFCIRC/26, 1961; INFCIRC/66, 1966)
Limited to items and materials transferred from other countries.
Still applies for Israel, India and Pakistan

NPT Nuclear Safeguards Agreement (INFCIRC/153, 1972)
"Full scope": covering all declared special nuclear material.
Limited to declared materials and facilities.

NPT Additional Protocol (INFCIRC/540, 1997)
Strengthen effectiveness and improve efficiency of nuclear safeguards.

Constraining Horizontal Nonproliferation

Nuclear Safeguards according to INFCIRC/153

"Full scope": covering all declared special nuclear material.

More than 900 facilities in 71 countries are under inspection.

There are 250 inspectors, costing $70 million per year.

- Accountancy and physical inventory of materials
- Containment and surveillance

Non-discriminatory approach —

- Not cost-effective (79% is spent in Canada, Europe, & Japan)

Limited to declared materials and facilities.

Verification of the Nuclear Nonproliferation Treaty

The Additional Protocol

Comprehensive declaration of current and planned materials and facilities

Regular updates of the declaration

Complementary access on short notice (24 hours)

Environmental sampling

- location specific (swipe samples)
- wide-area (to be decided by the Board of Governors)

In addition

Open source information

Satellite imagery

Detection of Horizontal Proliferation

Example: Natanz, Iran

Apparent attempt to hide an underground uranium centrifuge enrichment facility

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Analysis of North Korea’s Nuclear Test

On October 9, 2006, North Korea announced that it had carried out an underground nuclear test.

One week later, the Office of the Director of National Intelligence confirmed detection of radioactive debris and stated that North Korea had conducted a nuclear explosion with a yield of less than 1 kiloton

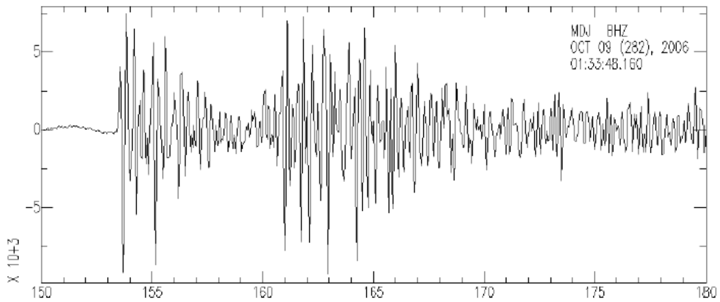
Although the test did not succeed as planned, North Korea might have been testing a lower-yield design.

- How powerful was the explosion?
- Was it a nuclear test?
- If nuclear, was the test successful?

Source: Richard L. Garwin, Frank N. von Hippel, A Technical Analysis: Deconstructing North Korea’s October 9 Nuclear Test, www.armscontrol.org/act/2006_11/tech.asp

Frederick K. Lamb © 2011

Detection of North Korea’s Nuclear Test



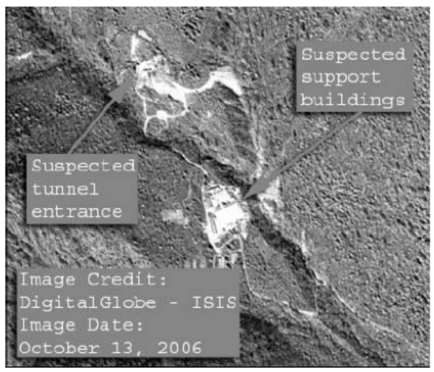


Figure 3: Satellite imagery of the suspected test site (location 41.28 N 129.08 E)[14]

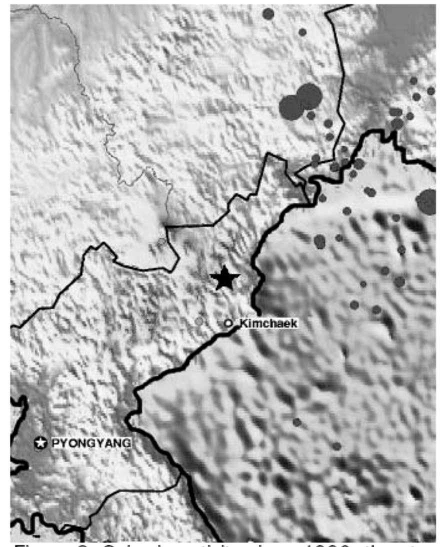


Figure 2: Seismic activity since 1990; the star shows the location of the North Korean nuclear test explosion
Source: United States Geological Survey (USGS) – National Earthquake Information Center (NEIC)

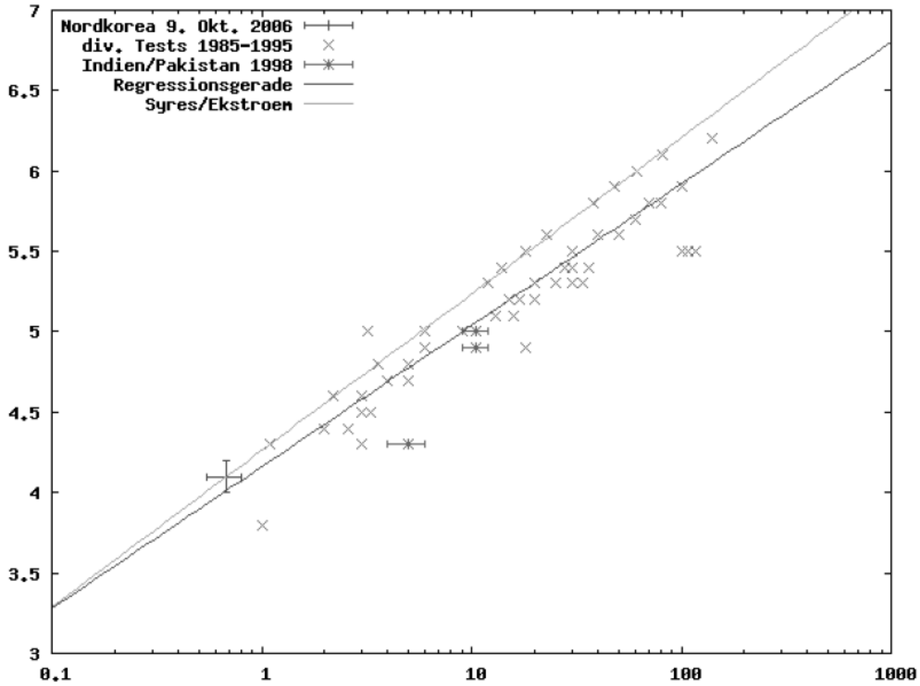
Source: Martin B. Kalinowski, Ole Ross, Analysis and Interpretation of the North Korean Nuclear Test, INESAP Information Bulletin No. 27, Dec. 2006

Parameters of seismic analysis of the North Korean event on October 9, 2006

Institution	Origin Time	Latitude	Longitude	Stations	Magnitude
IPC GS RAS[2]	1:35:26	41.31	128.96	11	4.0
USGS/NEIC[3]	1:35:27	41.294	129.134	17	4.2
IDC (CTBTO)[4]	1:35:28.33	41.2796	129.014	15	4.0

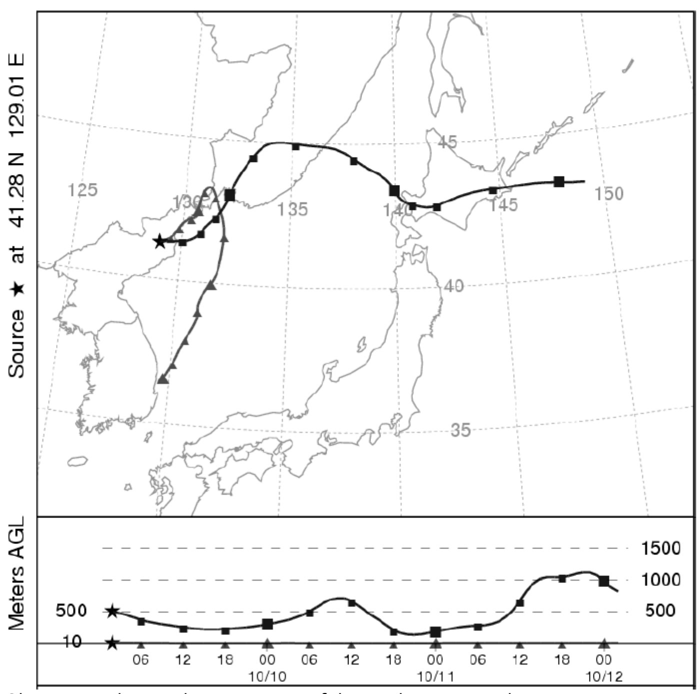
Source: Martin B. Kalinowski, Ole Ross, Analysis and Interpretation of the North Korean Nuclear Test, INESAP Information Bulletin No. 27, Dec. 2006

Nuclear test yields (kt TNT equivalent) and measured body wave magnitude mb



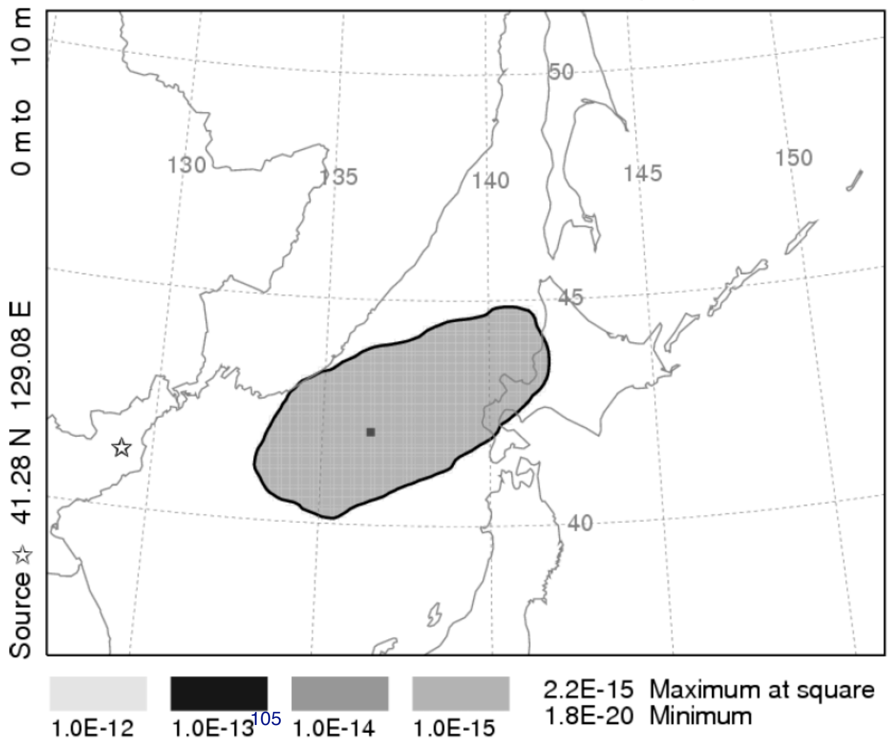
Source: Martin B. Kalinowski, Ole Ross, Analysis and Interpretation of the North Korean Nuclear Test, INESAP Information Bulletin No. 27, Dec. 2006

Wind field trajectories calculated with HYSPLIT from North Korean test site for two starting heights



Source: Martin B. Kalinowski, Ole Ross, Analysis and Interpretation of the North Korean Nuclear Test, INESAP Information Bulletin No. 27, Dec. 2006

HYSPLIT model of plume above Sea of Japan 48 hours after explosion with dispersion factor of 10–15 averaged from 0–500 m above ground level



2006 North Korean Test: Uncertainties

North Korea informed China to conduct a nuclear test, with a yield in the range of 4 kilotons.

Such an explosion in hard rock would produce a seismic event with a magnitude of about 4.9 on the Richter scale, uncertainty in seismic magnitude of 0.5: shift in yield by factor 4.6

- The U.S. Geological Survey reported a seismic magnitude of 4.2.
- South Korea's state geology research center reported magnitude between 3.58 and 3.7, and estimated a yield equivalent to 550 tons TNT.
- Terry Wallace (Los Alamos): estimated a yield of 0.5 to 2 kilotons, with 90 percent confidence that the yield is less than 1 kiloton
- Lynn R. Sykes (Columbia University) estimated a yield of 0.4 kilotons, with 68 percent confidence that it was between 0.2 and 0.7 kilotons and 95 percent probability that it was less than 1 kiloton

→Very effective detection of underground sub-kiloton explosions

Richard Garwin, Frank von Hippel, Deconstructing North Korea's October 9 Nuclear Test, www.armscontrol.org/act/2006_11/tech.asp

Frederick K. Lamb © 2011

Was It a Nuclear Test?

Possible conventional explosion: Five hundred tons of mixture of ammonium nitrate and fuel oil (ANFO), an inexpensive explosive used in mining, would fill the last 60 meters of a 3m x 3m tunnel

Radioactivity was detected in the atmosphere of the region two days after the explosion

North Korea has enough plutonium to make several Nagasaki-type weapons, and a clandestine uranium-enrichment program

Detection of radioactive xenon isotopes, Xe-133 and Xe-135 (half-lives 5 five days, 0.4 days) indicate an underground nuclear test

Because Xe-135 decays much more rapidly, the ratio of their concentrations in the plume provides a rough measure of the number of Xe-135 half-lives and therefore the time since the test

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Was It a Successful Test?

Low yield of the 2006 North Korean test

Nagasaki bomb (20 kt): tons of high explosive implode solid subcritical sphere of plutonium to higher density to make it supercritical.

J. Robert Oppenheimer: 2 percent chance that the yield could be lower than 1 kiloton if neutron started the chain reaction just when the plutonium first became critical.

Perhaps North Korean weapon designers tried to go directly to a small weapon of 500-1,000-kilogram for use on missiles

→ Yield of explosion was much less than design yield,

→ Little faith in North Korean nuclear-weapon stockpile

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iClicker Question

The Comprehensive Nuclear Test Ban Treaty (CTBT) was opened for signature in what year?

A. 1981

B. 1987

C. 1991

D. 1993

E. 1996

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Blank

Frederick K. Lamb © 2011

iClicker Answer

The Comprehensive Nuclear Test Ban Treaty (CTBT) was opened for signature in what year?

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E. 1996

Frederick K. Lamb © 2011

iClicker Question

The Intermediate Nuclear Forces (INF) Treaty was signed in what year?

A. 1981

B. 1987

C. 1991

D. 1993

E. 1996

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Blank

Frederick K. Lamb © 2011

iClicker Answer

The Intermediate Nuclear Forces (INF) Treaty was signed in what year?

A. 1981

B. 1987

C. 1991

D. 1993

E. 1996

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iClicker Question

The Strategic Arms Reduction (START I) Treaty was signed in what year?

A. 1981

B. 1987

C. 1991

D. 1993

E. 1996

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Blank

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iClicker Answer

The Strategic Arms Reduction Treaty (START I) was signed in what year?

A. 1981

B. 1987

C. 1991

D. 1993

E. 1996

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iClicker Question

The Strategic Arms Reduction Treaty II (START II) was signed in what year?

A. 1981

B. 1987

C. 1991

D. 1993

E. 1996

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iClicker Answer

The Strategic Arms Reduction Treaty II (START II) was signed in what year?

A. 1981

B. 1987

C. 1991

D. 1993

E. 1996

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Module 8: Nuclear Arms Control

Nuclear Safeguards

(slides prepared by 10p280 TA Matthew Duchene)

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Key Safeguards Terms

• Significant Quantity (SQ): the approximate quantity of nuclear material in respect of which the possibility of manufacturing a nuclear explosive device cannot be excluded.

Material	Significant Quantity (SQ)
Plutonium (<80% Pu-238)	8 kg
U-233	8 kg
HEU (>20% U-235)	25 kg
LEU (<20 % U-235)	75 kg

• Timely Detection: the time within which a detection must be made is based on the time required to weaponize the material in question.

Material Form	Conversion Time
Pu, HEU or U-233 metal	7-10 Days
Pu, HEU or U-233 oxides or nitrates (pure and unirradiated)	1-3 Weeks
Pu, HEU or U-233 in irradiated fuels	1-3 Months
Uranium with < 20% U-235 or U-233	1 Year

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Diversion Methods

A facility operator may attempt to divert material through one of the following methods:

- Tampering with IAEA equipment
- Falsifying records
- Borrowing nuclear material from another site
- Replacing nuclear material with dummy material
- Preventing access to the facility.

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Safeguards Methods

Safeguards at nuclear facilities is carried out through various methods and tools that can be described by a few general categories:

- Nondestructive Assaying (NDA)
- Destructive Analysis (DA)
- Containment/Surveillance (C/S)
- Environmental Sampling (ES)

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Nondestructive Assay (NDA)

NDA tools can consist of any measurement device that does not destroy the sample.

- Mass scales
- Radiation detectors/neutron counters
- Cherenkov radiation viewing devices

Advantages:

- Can be operated in-situ, remotely
- Cost-effective

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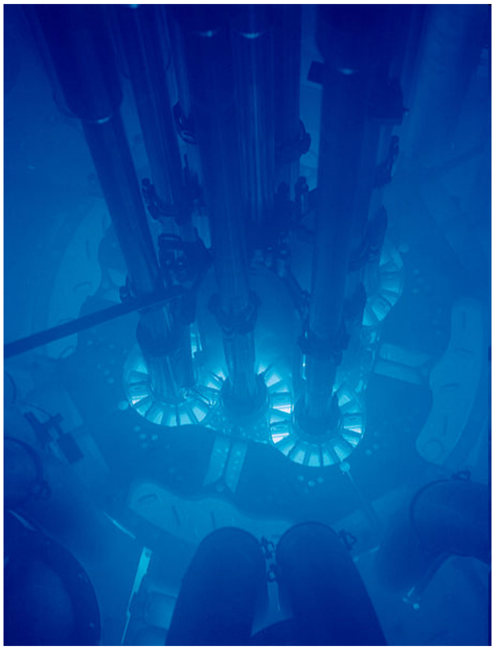
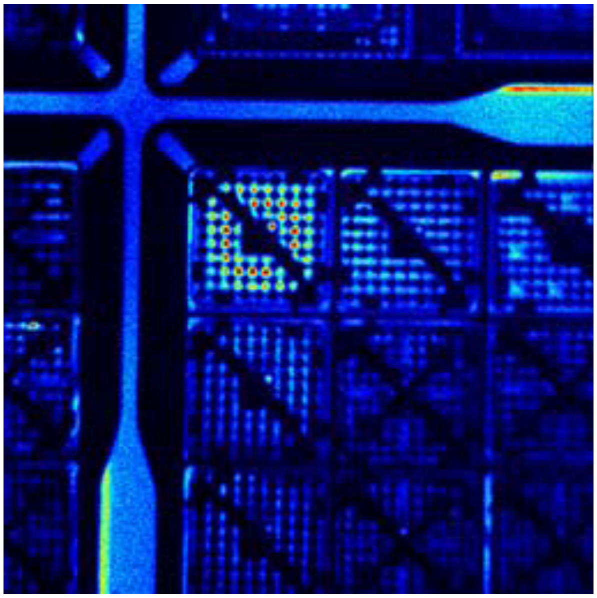
Cherenkov Radiation





Ref: Left, “Cherenkov Radiation.” Above, “Introduction to Nuclear Safeguards: Nondestructive Analysis.”

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Destructive Analysis (DA)

As the name implies, DA requires destruction of a small sample of material.

- Mass spectrometry
- Titration
- Radiochemical analysis

Advantages:

- More precise than NDA measurements
- Lower detections limits

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Environmental Sampling (ES)

•Part of the goal for IAEA safeguards is to provide assurance of the absence of undeclared nuclear activity in a state

•All nuclear processes emit trace particles of material into the environment.

•ES helps the IAEA to reach a conclusion on undeclared activity through various environmental signatures and observables

- May consist of:
  —Soil and water samples
  —Smears
  —Bulk or particle analysis

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Sampling and Analysis of Atmospheric Gases

Figure 10: Basic Methodology 1
A mobile on-site laboratory samples and concentrates atmospheric-borne pollutants. Local meteorological conditions and the GPS location are also recorded.

Figure 11: Basic Methodology 2
Samples are brought to a field laboratory for analysis.

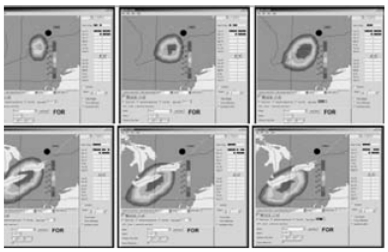

Figure 12: Basic Methodology 3
The sample analysis data is combined with meteorological data and suitable atmospheric modelling to provide an estimate of the source direction.

Figure 13: Basic Methodology 4
The airborne material is identified and the

Need: To detect the presence and nature of nuclear fuel cycle process activities at suspected locations

Application: Away-from-site (stand-off) detection

Proposed Solution:

Use on-site LIBS to determine the nature and history of compounds and elements

Source: J. Whichello, et al., IAEA Project on Novel Techniques, INESAP Information Bulletin No. 27, Dec. 2006

Laser-Induced Breakdown Spectroscopy (LIBS)

Need: To determine whether, or not, an undeclared location has been used previously for storing radiological material

Application: On-site verification; Complementary access inspections

Proposed Solution: Use OSL to measure the radiation-induced signature retained in many common building materials.

Figure 5: Basic Methodology 1
Unidentified materials found during an on-site complementary access inspection.

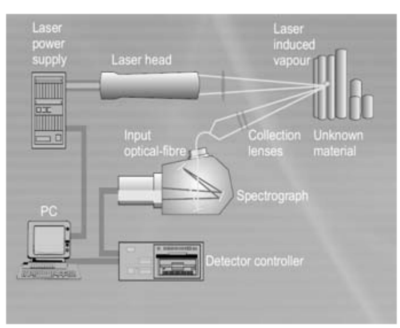

Figure 6: Basic Methodology 2
LIBS is comprised of (i) a laser system to ablate the surface of the material to be analyzed to create a micro-vapour, and (ii) a spectrometer to generate a spectroscopic profile of the micro-vapour's constituent components.

Figure 7: Basic Methodology 3
A trained IAEA inspector operates the LIBS unit on-site. The spectroscopic profile is compared to those in its library to determine the material's make-up and history.

Source: J. Whichello, et al., IAEA Project on Novel Techniques, INESAP Information Bulletin No. 27, Dec. 2006

Light Detection and Ranging (LIDAR)

Need: Detect presence and nature of nuclear fuel cycle process activities at suspected locations

Application: Away-from-site (stand-off) detection

Proposed Solution: Use a mobile LIDAR laboratory in the vicinity of a suspected site to detect the presence of characteristic gaseous compounds, emanating from nuclear fuel cycle processes into the atmosphere.

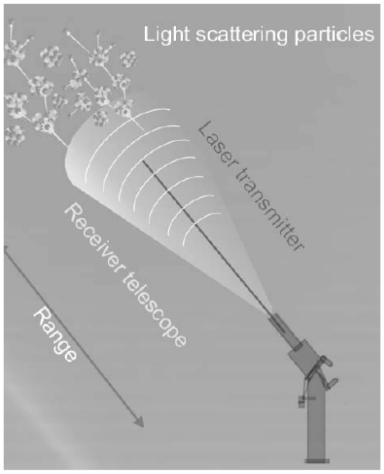

Figure 8: Basic Methodology 1
LIDAR methods are used routinely by environmental monitoring agencies to determine the presence of pollutants in the atmosphere.

Figure 9. Basic Methodology 2
A mobile LIDAR travels to the vicinity of a suspected location engaged in undeclared nuclear fuel cycle processes. A laser, tunable to precise wavelengths (λ), selectively stimulates specific airborne molecules emanating as gaseous compound from the process. A light-sensitive telescope scans the atmosphere, detecting the presence, or absence, of the stimulated molecules.

Source: J. Whichello, et al., IAEA Project on Novel Techniques, INESAP Information Bulletin No. 27, Dec. 2006

Containment/Surveillance (C/S)

While assaying provides measurements for material accountancy, C/S is used for area monitoring and to ensure that data is not falsified.

Some C/S items include:

- Surveillance cameras
- Area monitors
- Seals/Tags
- Tamper indicating devices

Measurement Errors

Material Unaccounted For (MUF): The accounting difference between the amount of recorded material transferred in and out of a facility and recorded inventory at the beginning and end of a particular reporting period.

MUF ≡ (Starting Inventory + Inputs - Outputs - Ending Inventory)

• MUF is never equal to zero for any facility!

• MUF can be both positive and negative (material created or lost).

• Each variable that contributes to the MUF calculation is based on *imperfect* measurements to quantify the amount of nuclear material in the facility.

• Quantity measurements are imperfect because of inherent sampling errors.

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Measurement Errors (cont'd)

•Measurement uncertainty can be divided into two categories:

- Random errors
- Systematic errors

•Random errors are the statistical errors that are inherently taken into account with any measurement, and are based on the level of precision of the measuring instrument.

•Systematic errors are measurement errors that remain constant over repeated measurements. A systematic error can be caused by a poorly calibrated instrument and will propagate throughout the entire system.

•Uncertainty grows larger as it propagates through a system.

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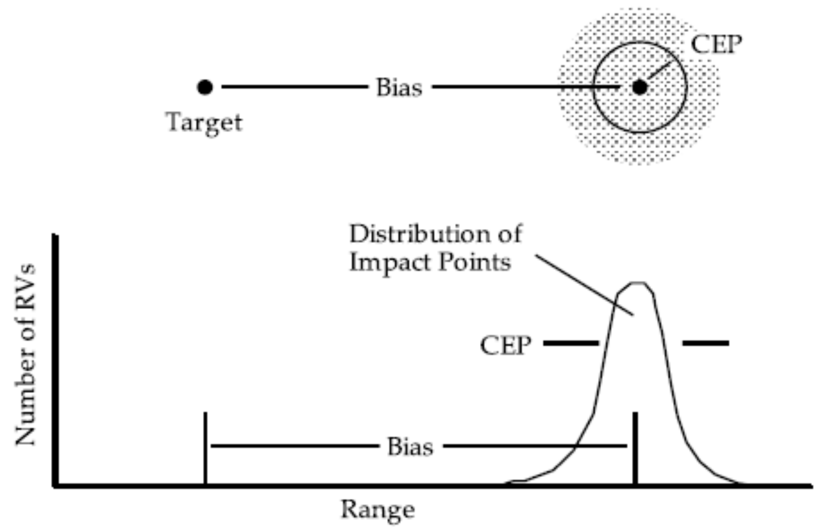
Familiar Concept?

Distribution of RV impact points —



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Measurement Errors (cont’d)

But how is MUF connected to measurement errors?

•When establishing safeguards at a facility the IAEA sets “confidence levels” based on the total error (random and systematic) of the measurement. The confidence levels are set based on statistics.

•The numerical value of the uncertainty is expressed as “sigma” or σ:

Sigma Level	Percent Confidence
± 1ó	68% Confidence
± 2ó	95% Confidence
± 3ó	99% Confidence

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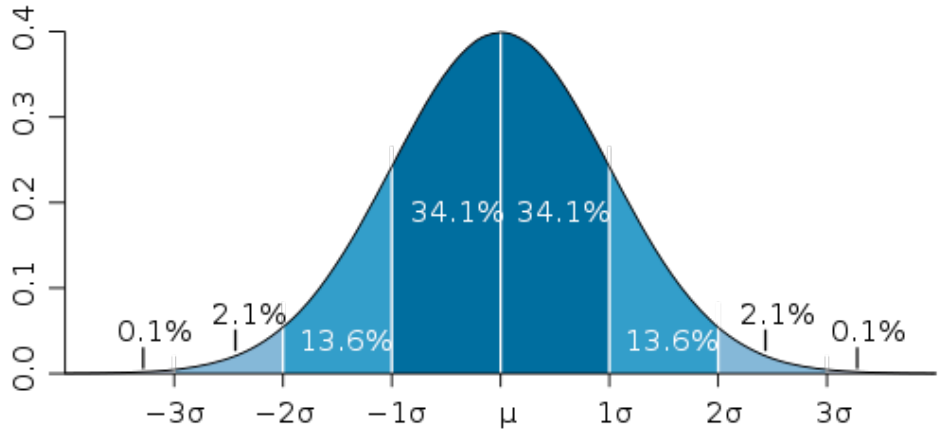
Confidence Levels



Sigma Level	Percent Confidence
± 1ó	68% Confidence
± 2ó	95% Confidence
± 3ó	99% Confidence

Ref: "Standard Deviation"

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Measurement Error Example

Let's use a basic example to illustrate the connection between MUF, measurement errors and the Sigma intervals.

•Suppose we are running safeguards on a civilian reprocessing plant.

- A reprocessing plant receives spent nuclear fuel, separates out the high level radioactive waste, and repackages the fuel to be used again in a reactor.
- A major safeguards concern is the diversion of separated plutonium.

•The Rokkasho reprocessing plant handles over 800 metric tons of heavy metal annually. (Approximately 8 metric tons of plutonium/year.)

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Example (cont'd)

If the total analytical error (random and statistical) for safeguards at Rokkasho is ~0.5%, then a 1σ error on one throughput will give ~40 kg Pu per year.

- 2σ will give you 80 kg, or ~6.67 kg/month
- 3σ will provide ~10 kg/month

With a Significant Quantity value of 8 kg for Pu, this situation does not meet the goal for timely detection, and the quality of the overall safeguards will have to be improved.

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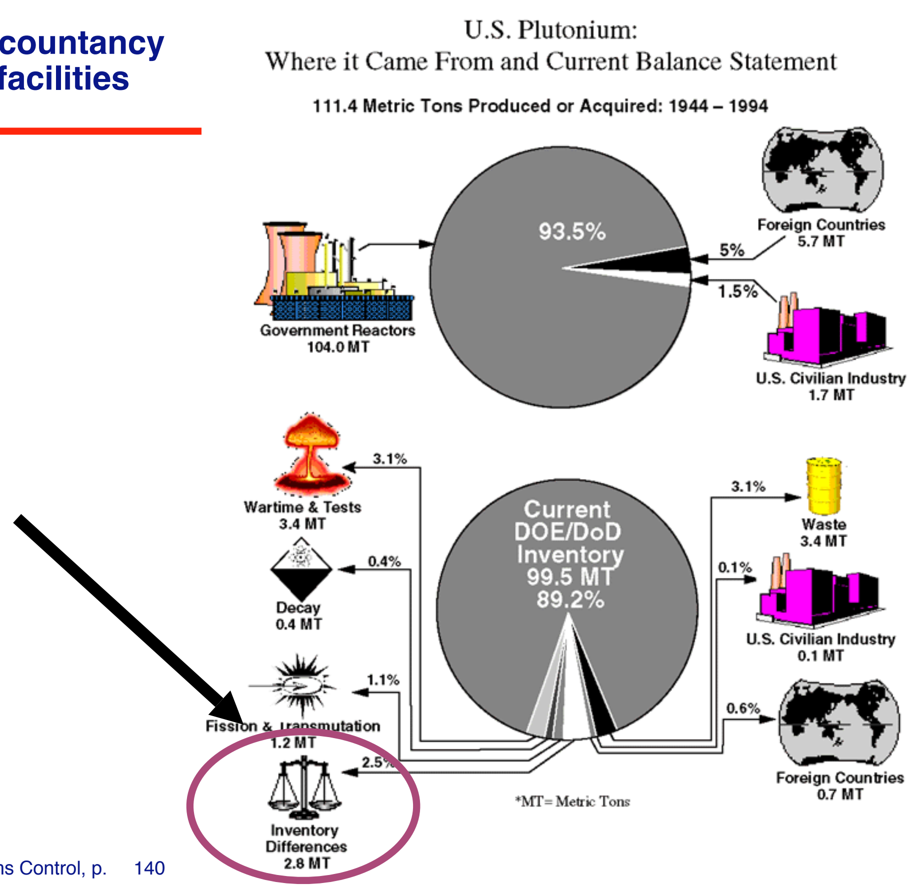
Problem with accountancy at bulk material facilities

MUF

= Material Unaccounted For

The problem of bulk material accountancy.



Limits of Material Accountancy

Other examples —

United Kingdom (Sellafield)

MUF =	2003:	- 19.1 kg
	2001:	- 5.6 kg
	1999:	- 24.9 kg
	1998:	+21.0 kg
	1996:	+15.0 kg

South Africa
6 nuclear weapons dismantled and HEU transferred to safeguards, but *material balance showed enough HEU for 7 weapons was produced*.

Solution: Cooperation and transparency.

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Basic Requirements for Verifying Nuclear Disarmament

1. No NW or relevant nuclear material held back and hidden

- Existing arsenals of nuclear weapons need to be disarmed completely
- Not retain single nuclear warhead or significant quantity of NW material
- No hidden inertia of the whole nuclear weapons production system.

2. No break-out of ban to develop or manufacture NW

a) "Disinvent" nuclear weapons, increase threshold against reinvention

- Dismantle infrastructure of existing nuclear weapons complex
- No research or testing for nuclear weapons, not maintain NW expert knowledge
- Control of dual-use science and technology

b) Prevent break-out from nuclear power or nuclear research programs

- Prohibition and timely detection of diversion of nuclear materials for NW
- No production of NW-usable materials nor removal from existing stocks
- Step-by-step, reduce existing stocks down to zero.

3. No intentions or reasons to acquire NW

- Convince that NW are inherently negative and possession is undesirable.

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References

•IAEA Safeguards Glossary (2001 Edition)

•"IAEA Safeguards Monitoring Systems & Science and Technology Challenges for International Safeguards," Mark Schanfein, Idaho National Laboratory, 2009.

•"Introduction to Nuclear Safeguards: Nondestructive Analysis," David Chichester, Idaho National Laboratory, 2009

•Image References:

- "Standard Deviation," Wikipedia
- "Cherenkov Radiation," Wikipedia

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Physics 280: Session 29

Final Exam Review Session:
Sunday, May 8th,144 Loomis, 7–8:30 PM

Final Exam:
Monday, May 9th, 151 Loomis, 7–10 PM

Plan for This Session

Video: "Countdown to Zero"

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May 3, 2010

Fact Sheet
Increasing Transparency in the U.S. Nuclear Weapons Stockpile

The United States is releasing newly declassified information on the U.S. nuclear weapons stockpile. Increasing the transparency of global nuclear stockpiles is important to non-proliferation efforts, and to pursuing follow-on reductions after the ratification and entry into force of the New START Treaty that cover all nuclear weapons: deployed and non-deployed, strategic and non-strategic.

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Stockpile. As of September 30, 2009, the U.S. stockpile of nuclear weapons consisted of 5,113 warheads. This number represents an 84 percent reduction from the stockpile's maximum (31,255) at the end of fiscal year 1967, and over a 75 percent reduction from its level (22,217) when the Berlin Wall fell in late 1989. The below figure shows the U.S. nuclear stockpile from 1945 through September 30, 2009.

Warhead Dismantlement. From fiscal years 1994 through 2009, the United States dismantled 8,748 nuclear warheads. Several thousand additional nuclear weapons are currently retired and awaiting dismantlement.

Non-Strategic Nuclear Weapons. The number of U.S. non-strategic nuclear weapons declined by approximately 90 percent from September 30, 1991 to September 30, 2009.

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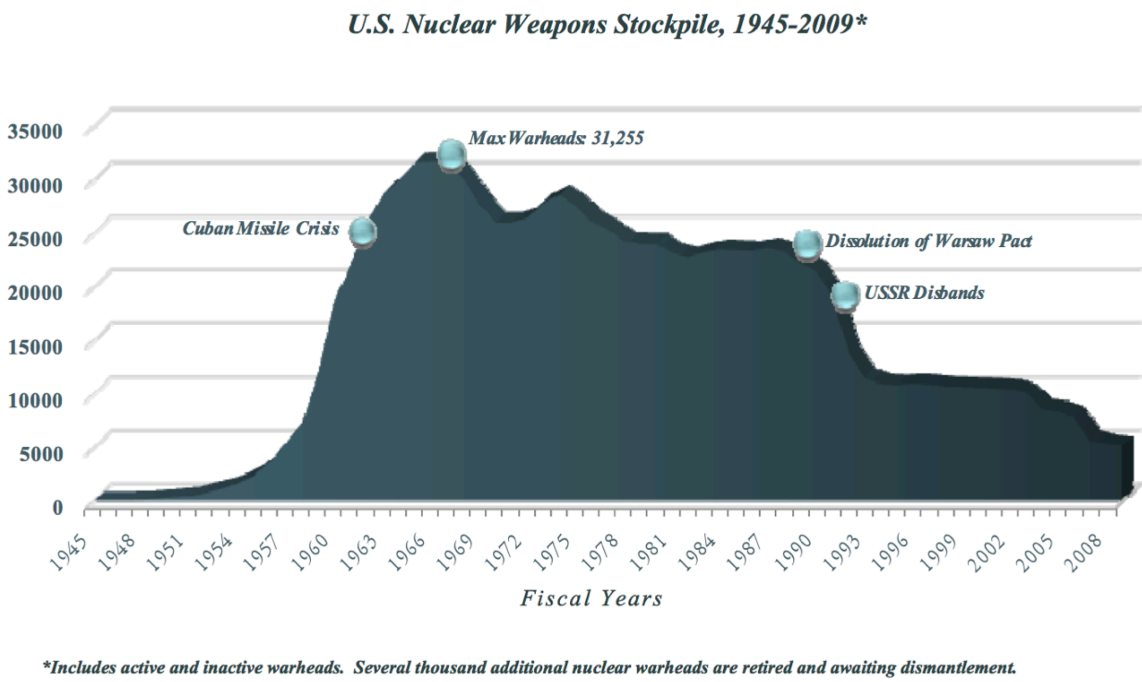
Session 29: News and Discussion



Module 8: Nuclear Arms Control

Video: Global Zero

Module 8: Nuclear Arms Control

Supplementary Slides

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Understanding Arms Control

- Arms Control is more than a collection of treaties
- Building blocks of the “international control regime”

  Example: the nuclear non-proliferation regime
- Establishes international norms and rules
- Is subject to interpretation by outside parties

  Example: the International Court of Justice advisory opinion regarding the use of nuclear weapons (see the next slide)

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Module 8, Part 2

Early History of Arms Control

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Early History of Arms Control

Control of conventional weapons has a long history with limited successes

- Pre-modern era
  - Examples; crossbows, dum-dum bullets, …
  - Sometimes religious or moral restrictions applying to all were attempted
  - Rarely were negotiations between equal parties involved
  - Typically, disarmament and arms control were imposed on the vanquished by the victorious

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Early History of Arms Control

- Modern era
  - Rush-Bagot (1817) was the first US arms control treaty; limits US and British naval vessels on the Great Lakes
  - 1925 Geneva Protocol: forbids use of poisonous gasses and bacteriological weapons against other signatories (US took until 1975 to ratify!)
  - 1928 Kellogg-Briand Pact (nations renounce war as an instrument of national policy)
  - 1920,1930, and up to about 1935 international Naval Agreements of various sorts to limit battleships, ...

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Early History of Arms Control

Arms Control took on a new urgency in the nuclear area —

- A first attempt to achieve nuclear arms control was implicit in Einstein's letter to President Roosevelt.
- Many scientists involved in the Manhattan project started to think about and discuss how to control nuclear weapons even before the Trinity test and the bombing of Japan. Some argued that nuclear weapons should not be used against people.
- Joseph Rotblat was the only scientist to leave the Manhattan Project when it became clear that none of the Axis powers were on the verge of obtaining the bomb. He continued his efforts to reduce the threat of nuclear weapons and was awarded the Nobel Peace Prize in 1995.

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Early History of Arms Control

The first formal nuclear arms control proposal was put forward by the US and was called *the Baruch Plan*

- Presented to the newly established UN in 1946
- Proposed that "atomic resources" be put under the control of the UN
- The US promised it would *eventually* give up all its NWs
- The terms of the plan were highly favorable to the US and unacceptable to the SU
- The 1949 nuclear test by the Soviet Union was its definitive response

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Early History of Arms Control

Subsequent nuclear arms control proposals were grandiose and impractical, often advocating "General and Complete (conventional and nuclear) Disarmament"

The UN continued to be an important forum for discussions and proposals

- UN Disarmament Commission created (1952)
  - Subcommittee of Five (US, UK, Fr, Ch, SU)
- Eighteen Nation Disarmament Committee in Geneva (1962-1969)
- Conference of the Committee on Disarmament (1969-1978)
- Committee on Disarmament (1979-1983)
- Conference on Disarmament (CD: 1984 - present)
- UN General Assembly, First Committee (Disarmament and International Security)

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Early History of Arms Control

The three existing NW states (the US, SU, and UK) began trilateral discussions outside the United Nations framework (China and France were not involved)

The importance of arms control was recognized in the United States by the creation of the U.S. Arms Control and Disarmament Agency (ACDA) in 1961 by President Kennedy

- The US was the first government to do this
- The Republican-dominated Senate brought intense pressure to bear on the Clinton administration to get rid of the ACDA and in 1998 it was eliminated
- ACDA's responsibilities were transferred to the State Department, but not its technical expertise

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The First Nuclear Arms Control Efforts Failed

- First attempts to control spread of nuclear arms Initiated by scientists of the Manhattan Project (see, e.g., the Franck Report)
  - Attempt was a failure but such is not uncommon when making policy in a *new and unfamiliar* area
- Follow-on attempts ("Complete and General Disarmament", "Atoms for Peace") under UN auspices were also failures
  - Nonetheless, important lessons were learned:
  - Attack a piece of the problem (e.g., nuclear testing)
  - Choose the best venue (e.g., bilateral, trilateral)

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International Court of Justice (ICJ) Advisory opinion of July 8, 1996, on the

Legality of the threat or use of nuclear weapons

A. Unanimously, There is in neither customary nor conventional international law any specific authorization of the threat or use of nuclear weapons;

B. By eleven votes to three,There is in neither customary nor conventional international law any comprehensive and universal prohibition of the threat or use of nuclear weapons as such;

C. Unanimously, A threat or use of force by means of nuclear weapons that is contrary to Article 2, paragraph 4, of the United Nations Charter and that fails to meet all the requirements of Article 51, is unlawful;

D. Unanimously, A threat or use of nuclear weapons should also be compatible with the requirements of the international law applicable in armed conflict particularly those of the principles and rules of international humanitarian law, as well as with specific obligations under treaties and other undertakings which expressly deal with nuclear weapons;

Art. 2(4) UN Charter: All Members shall refrain in their international relations from the threat or use of force against the territorial integrity or political independence of any state, or in any other manner inconsistent with the Purposes of the United Nations.

Art. 51: Nothing in the present Charter shall impair the inherent right of individual or collective self-defense if an armed attack occurs against a Member of the United Nations, until the Security Council has taken measures necessary to maintain international peace and security.

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Understanding Arms Control

International Court of Justice (ICJ)

Advisory opinion of July 8, 1996, on the

Legality of the threat or use of nuclear weapons

E. By seven votes to seven, by the President's casting vote, It follows from the above-mentioned requirements that the threat or use of nuclear weapons would generally be contrary to the rules of international law applicable in armed conflict, and in particular the principles and rules of humanitarian law; However, in view of the current state of international law, and of the elements of fact at its disposal, the Court cannot conclude definitively whether the threat or use of nuclear weapons would be lawful or unlawful in an extreme circumstance of self-defence, in which the very survival of a State would be at stake;

F. Unanimously, there exists an obligation to pursue in good faith and bring to a conclusion negotiations leading to nuclear disarmament in all its aspects under strict and effective international control.

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Understanding Arms Control

Compare with NPT Article VI

"Each of the Parties to the Treaty undertakes to pursue negotiations in good faith on effective measures relating to cessation of the nuclear arms race at an early date and to nuclear disarmament, and on a Treaty on general and complete disarmament under strict and effective international control."

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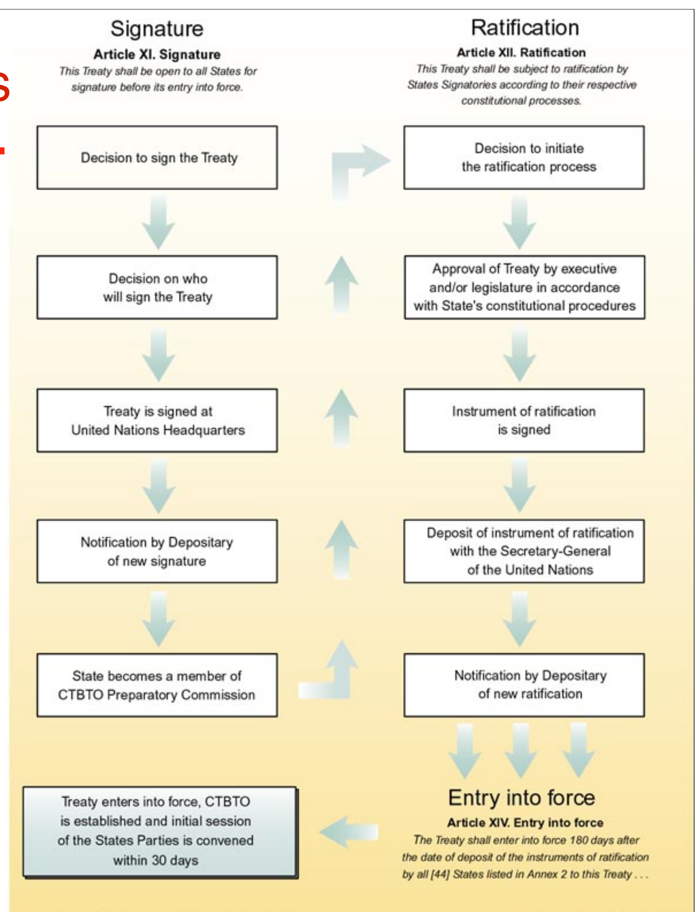
The Nature of Treaties

Process of signature, ratification, and entry into force.

Example:

Comprehensive Test Ban Treaty (CTBT)



Views on Nuclear Disarmament Verification

Canberra Commission (1996): "[b]efore states agree to eliminate nuclear weapons they will require a **high level of confidence** that verification arrangements would detect promptly any attempt to cheat the disarmament process."

U.S. National Academy of Sciences (CISAC 1998): "even the most effective verification system that can be envisioned would **not produce complete confidence** that a small number of nuclear weapons had not been hidden or fabricated in secret. More fundamentally, the **knowledge of how to build nuclear weapons** cannot be erased from the human mind. Even if every nuclear warhead were destroyed, the current nuclear weapons states, and a growing number of other technologically advanced states, would be **able to build nuclear weapons within a few months** or few years of a national decision to do so."

Steve Fetter: "Although no verification regime could provide **absolute assurance** that former nuclear-weapon states had **not hidden a small number** of nuclear weapons or enough nuclear material to build a small stockpile, verification could be good enough to **reduce remaining uncertainties to a level that might be tolerable** in a more transparent and trusting international environment. And although the **possibility of rapid break-out** will be ever present in modern industrial society, verification could provide the steady reassurance that would be necessary to dissipate residual fears of cheating."

→ Link between verifiability and security environment.

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Main Tasks for NWFW Verification

Baseline information exchange and data gathering: Identify the current status of the nuclear-weapons complex with reasonable accuracy without proliferating sensitive information.

Disarmament: Monitor the agreed path of reducing nuclear arms and eliminating the nuclear-weapons complex within tolerable limits of uncertainty and sufficient confidence.

Prevent rearmament: During the transformation to and within a nuclear-weapon-free world, observe any objects and detect any activities that might indicate a nuclear-weapons capability.

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Nuclear Safeguards

The Nuclear Safeguards topics:

- What are safeguards?
- Safeguards agreements
- Key terms and concepts
- Assaying
- Containment and surveillance
- Environmental sampling

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North Korea: Was It a Nuclear Test? (cont'd)

Fission of about 60 grams of plutonium would produce a yield of 1 kiloton and 2 grams each of Xe-133 and Xe-135, which can be detected at levels of about 1,000 and 100 atoms per cubic meter of air.

By the end of the third day, the plume would have traveled about 1,000 km in a zig-zag track over the Sea of Japan and might be 1 km high by 200 km wide (Martin Kalinowski).

If the radioactive xenon produced by a 1-kiloton underground explosion were released into the atmosphere at a typical rate of 0.1 percent per day of the undecayed xenon, the concentration of Xe-133 and Xe-135 in the plume would still be 100 and 10 times above the detection limit.

That would verify that it was a nuclear explosion.

Detection of Xe-133 alone after even a week or more could in itself confirm the nuclear nature of the explosion, but its trajectory would have to be "backcast" to make sure that it was not due to leakage from reactors in South Korea or Japan.

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