Physics 280: Session 25

Questions

Module 8: Nuclear Arms Control

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Nature and Goals of Arms Control

Example for Arms Control

Arms Control in the area of chemical warfare

First treaty: the 1925 Geneva Protocol

bans the use of chemical weapons.

Current: Chemical Weapons Convention (CWC)

Entered into force on April 29th 1997, Duration: Indefinite

Bans use & possession of chemical weapons

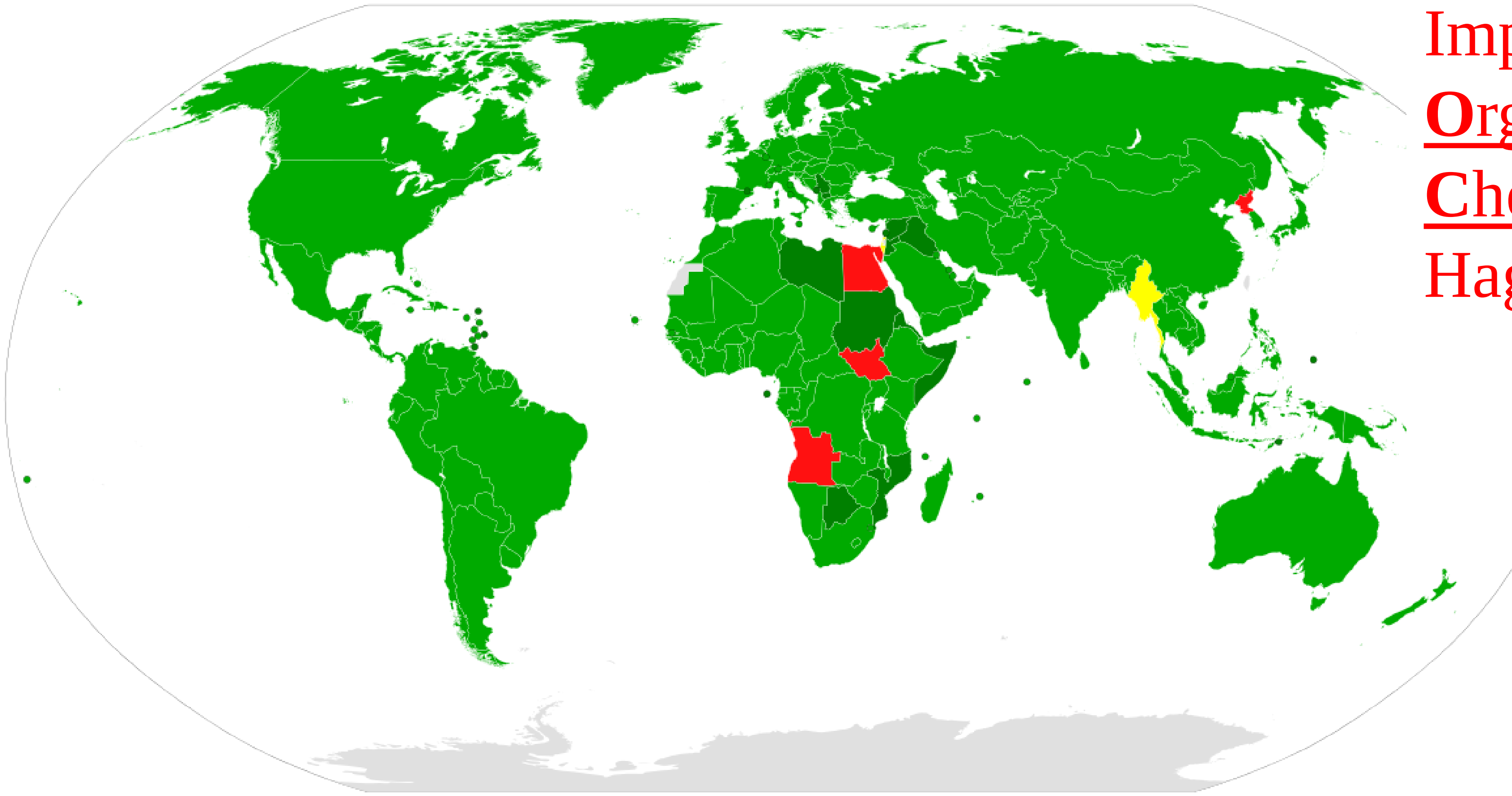
Defines time table for destruction of chemical weapons

Original deadline for destruction of all chemical weapons set in CWC:

April 29th 2012 – Lybia, Russia and US did not reached this goal.

2014 OPCW report: 87% of all declared chemical weapons have been destroyed (62,000 metric tons)

CWC Signed & Ratified by 190 Countries



Implementation is monitored by the **O**rganization for the **P**rohibition of **C**hemical **W**eapons located at The Hague, Netherlands.

OPCW was awarded the Nobel Peace Prize 2013

CWC provided framework to deal with crisis that arose from the use of chemical weapons by the Government of Syria in 2013.

The destruction of the Syrian chemical weapon stockpile is being monitored by the OPCW. On October 20th 2014 the OPCW announced that 98% of the Syrian chemical weapon stockpile has been destroyed.

Source: Arms Control Today, Paul F. Walker, December 2014

Figure 1: Eliminating Syria's Chemical Arsenal

The authority for the international project to destroy Syria's chemical arsenal came in September 2013 from a plan that was formulated by the Executive Council of the Organisation for the Prohibition of Chemical Weapons and endorsed by the UN Security Council. That plan was based on a U.S.-Russian framework agreement. In large part because of the ongoing civil war in Syria, the plan contemplated the removal of much of Syria's declared arsenal of 1,300 metric tons of chemical weapons material for destruction outside the country.

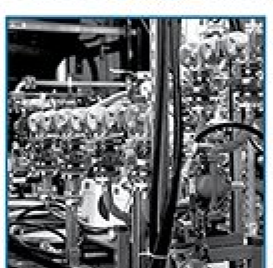
The removal was marked by delays, which Syria attributed to the hazard from rebel forces. The last chemicals left Syria on June 23, 2014, months behind schedule. By the end of October, however, 98 percent of the declared stockpile, including all of the most dangerous chemicals, had been destroyed.

Key Countries and Organizations Involved

Destroying Chemicals In Europe and the U.S.

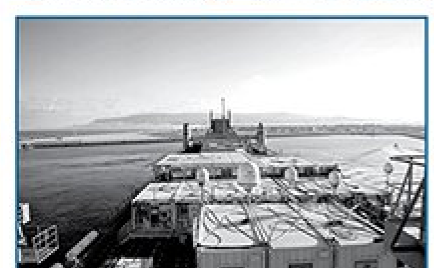
- After the transfer to the *Cape Ray* at Gioia Tauro, the *Ark Futura* went to the United Kingdom, where it off-loaded about 150 metric tons of chemicals weapons material for incineration at two sites in that country.
- The *Taiko*, a Norwegian freighter, went from Syria to Finland, where it delivered about 130 metric tons of chemicals for incineration.
- After the Finland stop, the *Taiko* traveled to Texas with several hundred metric tons of chemicals destined for incineration there.
- After completing the hydrolysis of the Syrian chemicals, the *Cape Ray* delivered to Germany 350 to 400 metric tons of effluent from the neutralization of the sulfur mustard aboard the U.S. ship.
- The *Cape Ray* then continued on to Finland, which is incinerating the 6,000 metric tons of effluent from the neutralization of the DF.
- The ship returned to Virginia in mid-September.

Destroying Chemicals at Sea



- On July 7, the *Cape Ray*, operating in international waters in the Mediterranean Sea, began neutralizing the chemicals transferred from the *Ark Futura*.
- The chemicals—the sarin precursor DF and a small amount of sulfur mustard—were neutralized in two mobile hydrolysis units that the *Cape Ray* was carrying.
- The neutralization was completed on August 17, well ahead of the announced schedule for that task.

'Transloading' in Gioia Tauro, Italy



- The Danish freighter *Ark Futura* carried 750 metric tons of Syrian chemical weapons agents from Latakia to the Italian port of Gioia Tauro.
- At Gioia Tauro, 600 metric tons of chemicals were transferred to the MV *Cape Ray*, a U.S. vessel.
- The transfer was completed on July 2.

Collecting Chemicals in Latakia, Syria

- Syrian chemical weapons agents were brought to the port city of Latakia in northwestern Syria from about 20 sites across the country.
- Syria was responsible for the transport of the chemicals to Latakia. Some of the equipment used in the operation was provided by other countries.
- From Latakia, an international convoy carried the chemicals away for destruction outside Syria.
- Syria's stockpile of isopropanol, which constituted about 10 percent of the declared arsenal of 1,300 metric tons, was destroyed within the country.

Note: This map is for illustrative purposes. It does not indicate precise areas of operation.

Source: Organisation for the Prohibition of Chemical Weapons, U.S. Department of Defense, Arms Control Association

Source: Arms Control Today, Paul F. Walker, December 2014

The Syrian chemical weapons destruction process in 2013 and 2014 has been a remarkable example of successful multilateral disarmament operations in the middle of a costly and dangerous civil war.

It has removed not only the threat of mass-casualty attacks with deadly nerve agents against soldiers and civilians in the Syrian civil war, but also the threat of chemical weapons use against neighboring countries.

Furthermore, it has set a precedent for Egypt and Israel, the other two suspected chemical weapons possessor states in the region, to join the near-universal CWC. The complete abolition of chemical weapons in the Middle East will be an important confidence-building measure for negotiations on a zone free of weapons of mass destruction in the region, as proposed by the 2010 Nuclear Nonproliferation Treaty (NPT) Review Conference.

Understanding Arms Control

Arms Control is one tool in the toolbox of international relations, which also includes

- Diplomacy
  - Bilateral
  - Multilateral (including the United Nations)
- Other security instruments
  - Political
  - Economic
  - Technological
  - Environmental
- Military Force
  - Self defense

    (If all else fails and action is justifiable within legal & ethical considerations)

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 (partial) disarmament
- It is not the answer to all problems

Arms Control is difficult and 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 a multilateral 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 threat of nuclear weapons including their use in war or in terrorist attacks
- Reduce the cost of a nuclear arms race
- Enhance international security and stability
- Facilitate international cooperation

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 Nuclear Weapons threaten the very existence of individual nations and human civilization.

Overview of Nuclear Arms Control Treaties

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) =
  Anti-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 in force yet
- 2002 Strategic Offensive Reductions Treaty (SORT)
- 2011 New START

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)

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),*
  Ratified in 1996 in Senate, Senate did not ratify 1997 START II addendum
  Ratification by Russia in 2000 conditional on US ratification of addendum
- *1996 : Clinton — Comprehensive Test Ban Treaty (CTBT),*
  Senate did not ratify
- 2002 : Bush II — Strategic Offensive Reductions Treaty (SORT), approved
- 2010 : Obama — New Strategic Arms Reduction Treaty (New START), approved

The Nature of Treaties

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.

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.

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

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.

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

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

An “Executive Agreement” is an agreement between the heads of two (or more) states and is not legally binding in the framework of the Vienna Convention. However, executive agreements are regulated under US law and are an alternative form to enter international agreements for the US.

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

Nuclear Arms Control During the Cold War

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

The 1963 Limited Test Ban Treaty

Provisions —

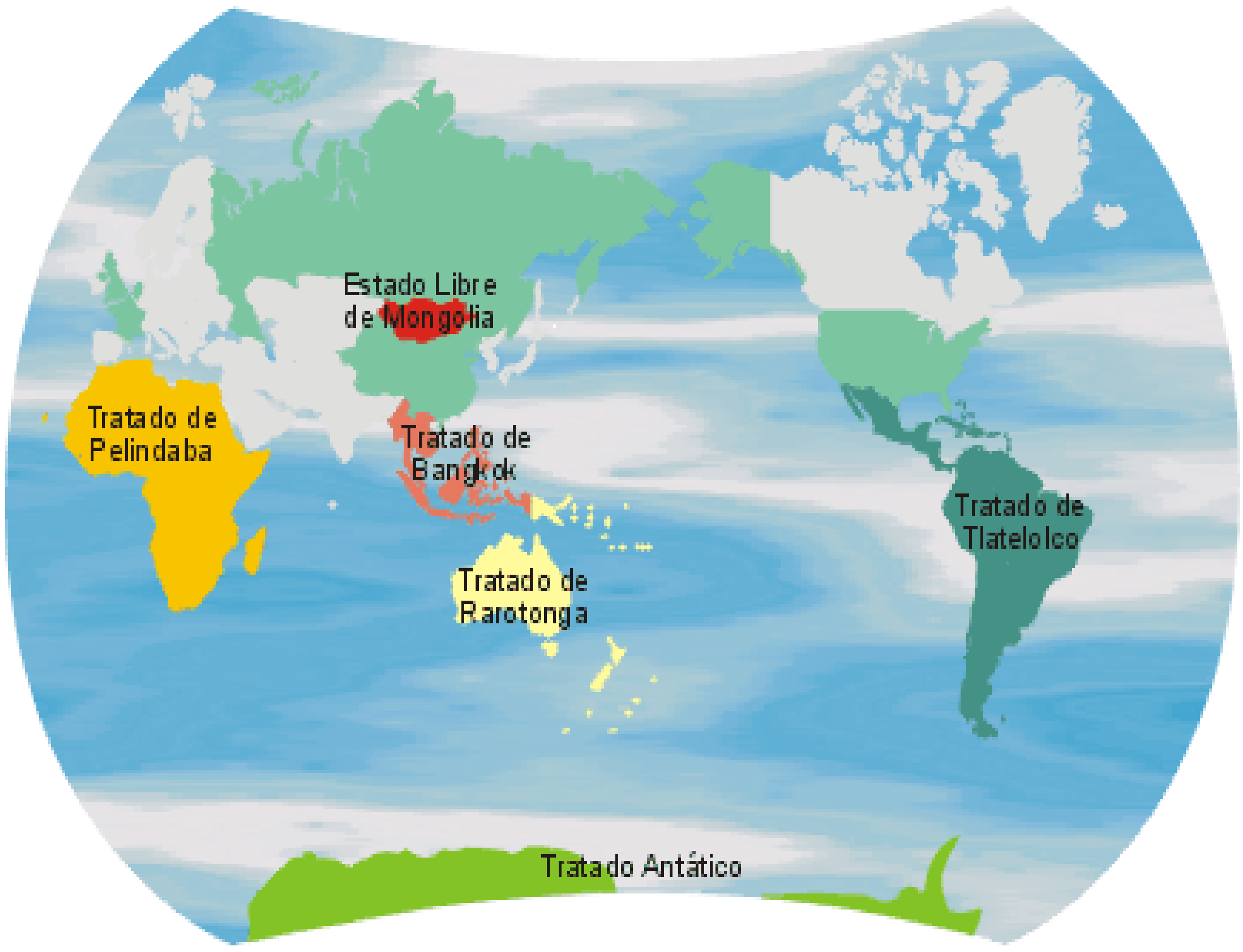
- A two-page treaty (see the PHYS-280 documents web page)
- Bans “any nuclear weapons test explosion, or any other nuclear explosion” “in the atmosphere; beyond its limits, including outer space; or underwater”
- “in any other environment if such explosion causes radioactive debris to be present outside 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

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 opponents of the CTBT as an excuse not to ratify it in the U.S. Senate)
- 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

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

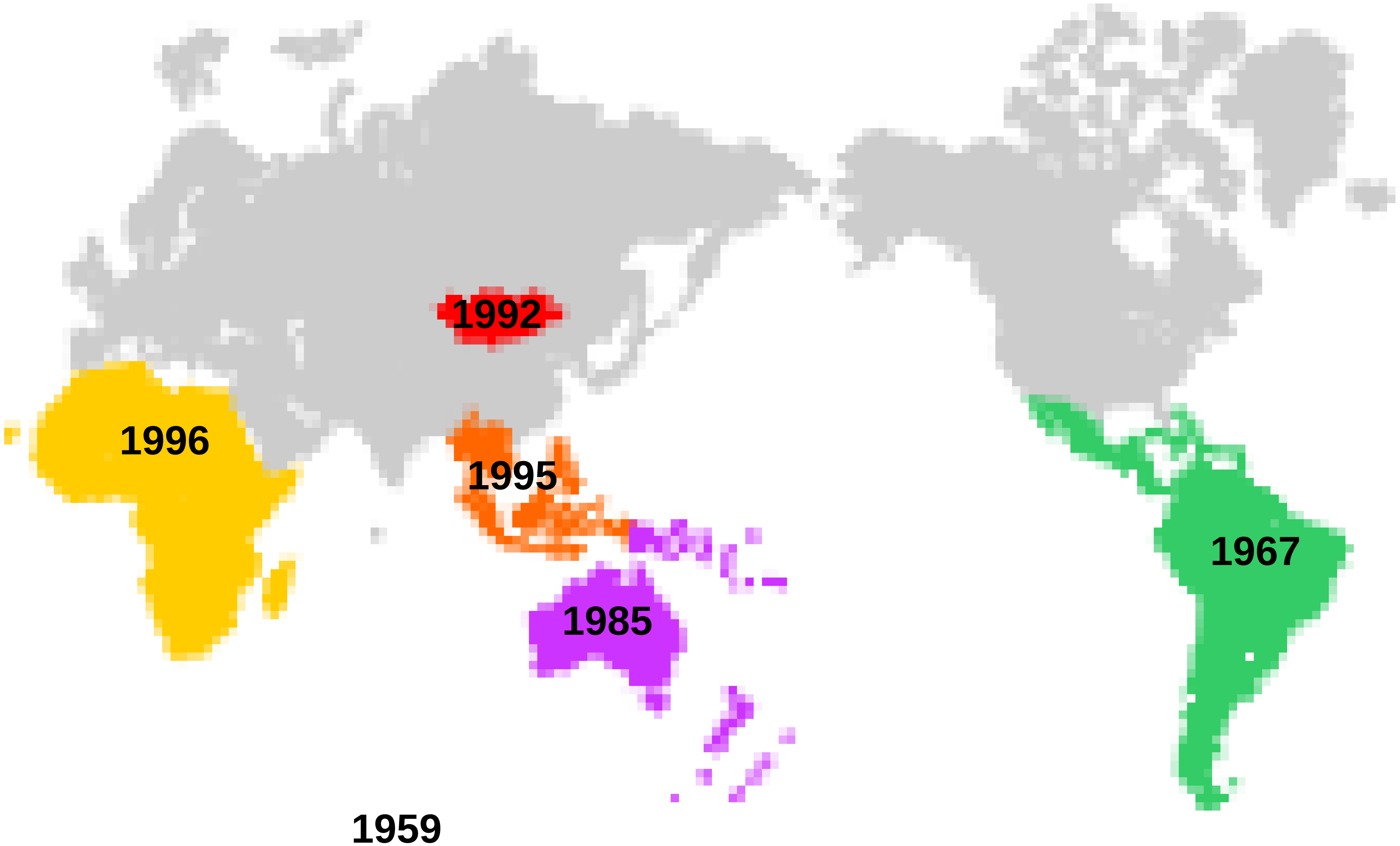


Other “Nuclear Free Zones”

- 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

Nuclear-Weapon-Free Zones: Timeline

Almost the whole southern hemisphere is covered by Nuclear-Weapon-Free Zone Treaties



Nuclear-Weapon-Free Zones

Latin American Nuclear Free Zone (LANFZ) Treaty (1967)

- Also known as the "Treaty of Tlatelolco," the area of Mexico City where the diplomats assembled

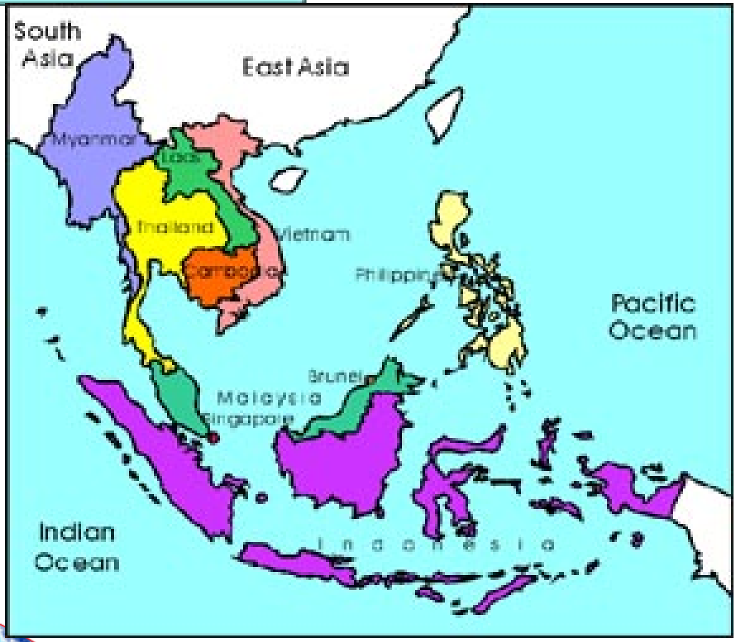
- Signed in 1967, is of indefinite duration
- Came about through the efforts of five Latin American Presidents

  (Bolivia, Brazil, Chile, Ecuador, and Mexico)

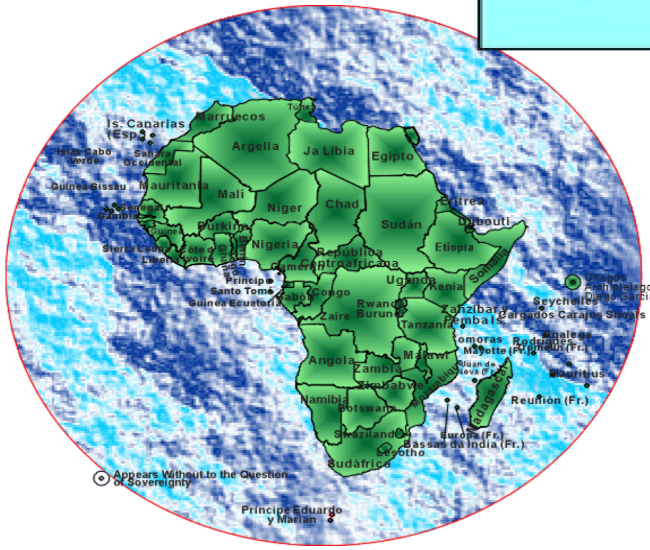
- Motivation came from the 1962 Cuban missile crisis
- The 24 Latin American signatories agree not to to not develop or introduce NWs
- The four countries outside of region (US, UK, Neth, Fr) agree in a signed protocol to apply the provisions to their territories in LA
- All five NPT NW states agree in second protocol not to introduce NWs into region of LA

Nuclear-Weapon-Free Zones

- 1959 Antarctic Treaty (first post-WWII treaty)
  - — Entire continent a nuclear free zone
  - — Numerous other restrictions on state behavior that are unrelated to nuclear weapons
- 1985 South Pacific NWFZ (Treaty of Raratonga)



- 1995 South-East Asian NWFZ (Treaty of Bangkok)
- 1996 African NWFZ (Treaty of Pelindaba)



Physics 280: Session 26

Midterm grades posted

289 (multiple choice) + 22 (essay question) = 311 (total)
Shifted average by 12 points from 81.4% to 85.3%

Extra Credit Opportunity D: 4-28, Spurlock Auditorium
“ISIS and the global rise of religious Rebellions”

Questions

News (https://www.washingtonpost.com/news/powerpost/wp/2016/04/04/the-nuclear-physicist-who-helped-reduce-the-world-stockpile-of-nuclear-arms-retires/)

Module 8: Nuclear Arms Control cont’d

Horizontal Nuclear Non-Proliferation

1955: Atoms for Peace

(https://www.iaea.org/newscenter/multimedia/videos/atoms-peace-speechsee) 1st video

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)

(https://www.iaea.org/newscenter/multimedia/videos/iaea-focus) 2nd video

Example: Inspection of the Nuclear Program in Iran by the IAEA During P5+1 Negotiations

IAEA
Atoms for Peace

Board of Governors

GOV/INF/2014/10
Date: 17 April 2014

Restricted Distribution
Original: English

For official use only

Status of Iran's Nuclear Programme in relation to the Joint Plan of Action

Report by the Director General

Building Trust: Inspection of the Nuclear Program in Iran by the IAEA

1. As foreshadowed in GOV/2014/2, this report provides information on the status of the Islamic Republic of Iran's (Iran's) nuclear programme in relation to the "voluntary measures" that Iran has agreed to undertake as part of the Joint Plan of Action (JPA) agreed between the E3+3 and Iran on 24 November 2013.[1] According to the JPA, the first step would be time-bound (six months) and renewable by mutual consent. The JPA took effect on 20 January 2014.[2]

2. The Agency confirms that since 20 January 2014, Iran has:

   i. not enriched uranium above 5% U-235 at any of its declared facilities;

   ii. not operated cascades in an interconnected configuration at any of its declared facilities;

   iii. completed the dilution – down to an enrichment level of no more than 5% U-235 – of half of the nuclear material that had been in the form of UF_6 enriched up to 20% U-235 on 20 January 2014;[3]

Example, how arms control and existing instruments of arms control can create trust and can be used to provide valuable options in resolving international conflict.

It is important to remember that well concerted sanctions, the related diplomatic efforts and the strong US military presence have played a key role in brining Iran to the table.

In view of many diverting interests and a 30 year history of mistrust and conflict the outcome of the present negotiations remains highly uncertain.

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 + commitment to pursue reduction of nuclear arsenals**
  - —**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 negotiation is generally regarded as highly undesirable

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 2006, in 2009, in 2013 and in 2016. Accession of Kim Jong-un in 2011 has lead to present crisis with significant uncertainty with regards to North Korea's intentions.
- **Concerns that Iran may be close to acquiring nuclear weapons continue to exist**.

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 failed to produce a final communiqué

The 2010 NPT Five-Year Review was more successful

The 2015 NPT Five-Year Review failed to produce a final communique over resistance of NWS to advance disarmament, including schedule for negotiations for a middle east NWFZ.

Monitoring of NPT: IAEA Safeguard System

- 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 900 facilities in more than 70 nations.

2nd video

The 1997 NPT Additional Protocol

- Iraq case 1991: inability to detect clandestine nuclear activities suggests that IAEA nuclear safeguards are not comprehensive enough.
- 93+2 program to enhance efficiency and effectiveness of nuclear safeguards ➔ broader range of facilities, environmental sampling, inspections with short term notice
- Model for Additional Protocol (INFCIRC-540) in 1997
- As of December 2010 signed by 139 states, in force in 104 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

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

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 by many as a serious mistake in Cold War arms control
- 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

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 (Soviet invasion in Afghanistan). Both sides followed 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.
- 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

Jimmy Carter and Leonid Brezhnev signing SALT II in Vienna, June 18, 1979.

The Intermediate Nuclear Forces (INF) Treaty

- Intermediate-Range Nuclear Forces (INF) Treaty was signed on December 8, 1987; entered into force in1988

Anti-Perhsing II Peace Demonstration

- 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)

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 for reduction)
  - — 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

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

— 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)

Nuclear Arms Control: Post Cold-War

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

1992 Lisbon Accord

1993 START II

1996 CTBT

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

» Budapest Memorandum of 1994: Russia, US, UK provide security assurances to the Ukraine.

START II

- Bush-Yeltsin signed in Moscow January 3, 1993
- Strategic Nuclear Delivery Vehicle (SNDV) ceiling of 1,600 in START-I unchanged
- Total warhead ceiling reduced to 3,000–3,500
- Warhead counts
  - — 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)

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 delayed ratification over concerns of EU and NATO expansion in Eastern Europe. When finally ratified: subject to the provision that the US remain bound by the ABM Treaty.

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?

Physics 280: Session 27

Midterm grades updated to correct several errors
(swapped scantrons & errors in partial credit + multiple correct answers problems): 299 (multiple choice) + 22 (essay question) = 321 (total). Shifted average by 23 points from 78.1% to 85.3%

Extra Credit Opportunity D: 4-28, Spurlock Auditorium
“ISIS and the global rise of religious Rebellions”

Office hours take place, RPv2 due Thursday, 4-28 in class.

News

Module 8: Nuclear Arms Control cont’d

News

Race for Latest Class of Nuclear Arms Threatens to Revive Cold War

NY Times, 4-16-2016

点击查看本文中文版 | Read in Chinese

By WILLIAM J. BROAD and DAVID E. SANGER APRIL 16, 2016

The United States, Russia and China are now aggressively pursuing a new generation of smaller, less destructive nuclear weapons. The buildups threaten to revive a Cold War-era arms race and unsettle the balance of destructive force among nations that has kept the nuclear peace for more than a half-century.

American officials largely blame the Russian president, Vladimir V. Putin, saying his intransigence has stymied efforts to build on a 2010 arms control treaty and further shrink the arsenals of the two largest nuclear powers. Some blame the Chinese, who are looking for a technological edge to keep the United States at bay. And some blame the United States itself for speeding ahead with a nuclear "modernization" that, in the name of improving safety and reliability, risks throwing fuel on the fire.

http://www.nytimes.com/2016/04/17/science/atom-bomb-nuclear-weapons-hgv-arms-race-russia-china.html?_r=0

News

Race for Latest Class of Nuclear Arms Threatens to Revive Cold War

One of the few veterans of the Cold War in his administration, James R. Clapper, the director of national intelligence, told the Senate Armed Services Committee during his annual global threat assessment, “We could be into another Cold War-like spiral.” Yet it is different from Mr. Clapper’s earlier years, when he was an Air Force intelligence officer weighing the risks of nuclear strikes that could level cities with weapons measured by the megaton.

aten

Adversaries look at what the United States expects to spend on the nuclear revitalization program — estimated at up to $1 trillion over three decades — and use it to lobby for their own sophisticated weaponry.

Moscow is fielding big missiles topped by miniaturized warheads, and experts fear that it may violate the global test ban as it develops new weapons. According to Russian news reports, the Russian Navy is developing an undersea drone meant to loft a cloud of radioactive contamination from an underwater explosion that would make target cities uninhabitable.

The Chinese military, under the tighter control of President Xi Jinping, is flight-testing a novel warhead called a “hypersonic glide vehicle.” It flies into space on a traditional long-range missile but then maneuvers through the atmosphere, twisting and careening at more than a mile a second. That can render missile defenses all but useless.

The Obama administration is hardly in a position to complain. It is flight-testing its own hypersonic weapon, but an experiment in 2014 ended in a

News

Race for Latest Class of Nuclear Arms Threatens to Revive Cold War

spectacular fireball. Flight tests are set to resume next year. As part of the modernization process, it is also planning five classes of improved nuclear arms and associated delivery vehicles that, as a family, are shifting the American arsenal in the direction of small, stealthy and precise.

Moscow and Beijing, analysts say, are testing space weapons that could knock out American military satellites at the beginning of a nuclear war. In response, Washington is launching space observation satellites meant to deter and help defeat such attacks.

William J. Perry, the defense secretary under President Bill Clinton and one of the most influential nuclear experts in the Democratic Party, said he worried that Moscow would soon withdraw from the Comprehensive Test Ban Treaty of 1996 and begin perfecting new warheads in underground detonations. (The United States has abided by the treaty, but the Senate has never ratified it.)

For two decades, the main nuclear powers have observed a shaky global ban on testing, a central pillar of nuclear arms control.

"I'm confident they're working on a new bomb," Mr. Perry said in an interview, referring to Russian arms designers. "And I'm confident they're asking for testing." "It's up to Putin," he added.

Race for Latest Class of Nuclear Arms Threatens to Revive Cold War

Advocates of the American nuclear modernization program call it a reasonable response to Mr. Putin's aggression, especially his 2014 invasion of Crimea.

No major nuclear power is more threatened by the American advances than China, analysts say. A pre-emptive strike, they note, might easily do in its relatively small arsenal.

It sees Washington's hypersonic glider as a way to attack China without crossing the nuclear threshold, complicating its assessment of nuclear retaliation.

Dr. Twomey said Chinese leaders had similar apprehensions about growing numbers of antimissile interceptors on American warships in the Pacific as well as bases in California and Alaska.

Finally, he added, Beijing views Washington's nuclear modernization "with much trepidation." Specifically, he cited plans for a new guided bomb and the advanced cruise missile, as well as new delivery systems.

"Beijing has responded to these changes," Dr. Twomey testified, "and will likely continue to do so over the next decade."

"It's up to Putin," he added.

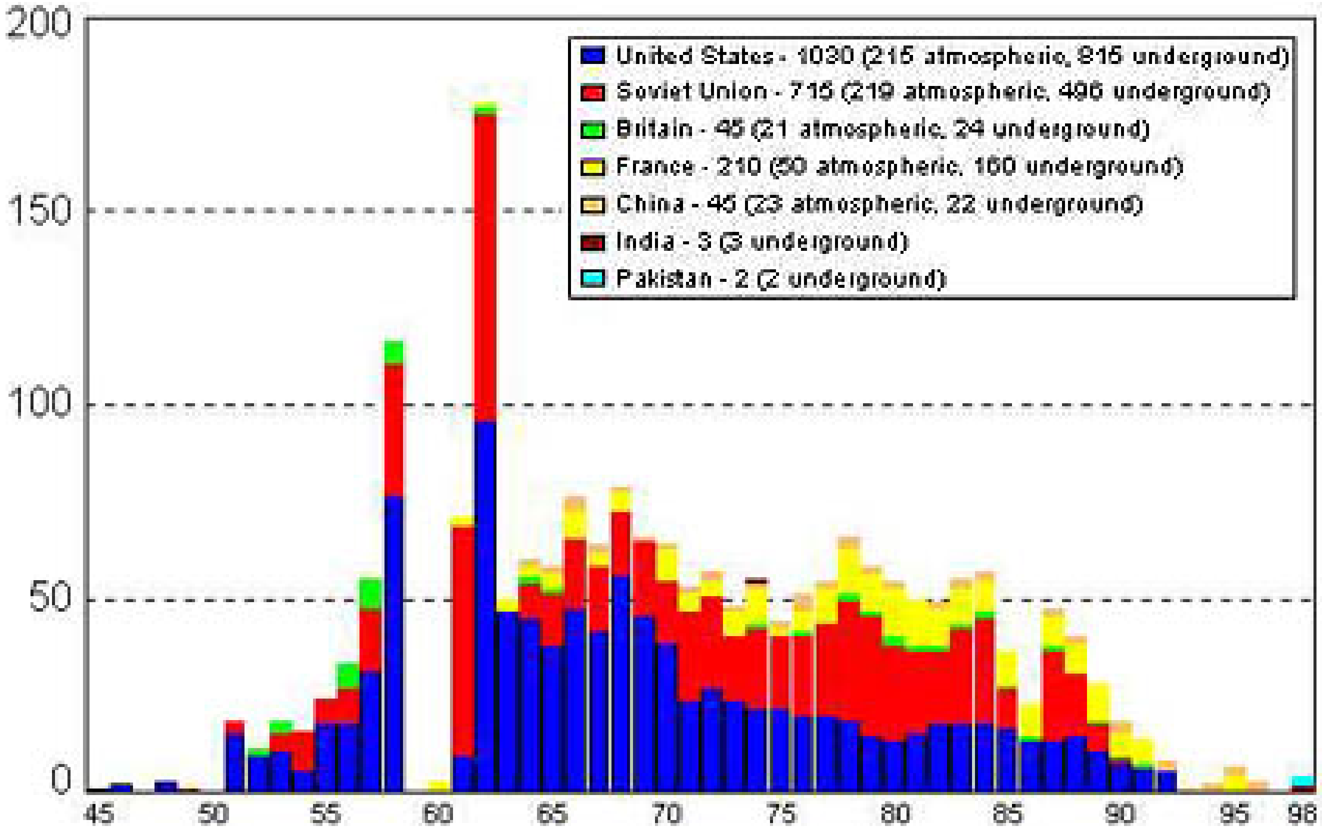
CTBTO preparatory commission for the comprehensive nuclear-test-ban treaty organization
PREPARATORY COMMISSION

Comprehensive Nuclear Test Ban Treaty

- Negotiated 1993–1996 at the Conference for Disarmament 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	—



Analysis of North Korea’s 2006 Nuclear Test

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

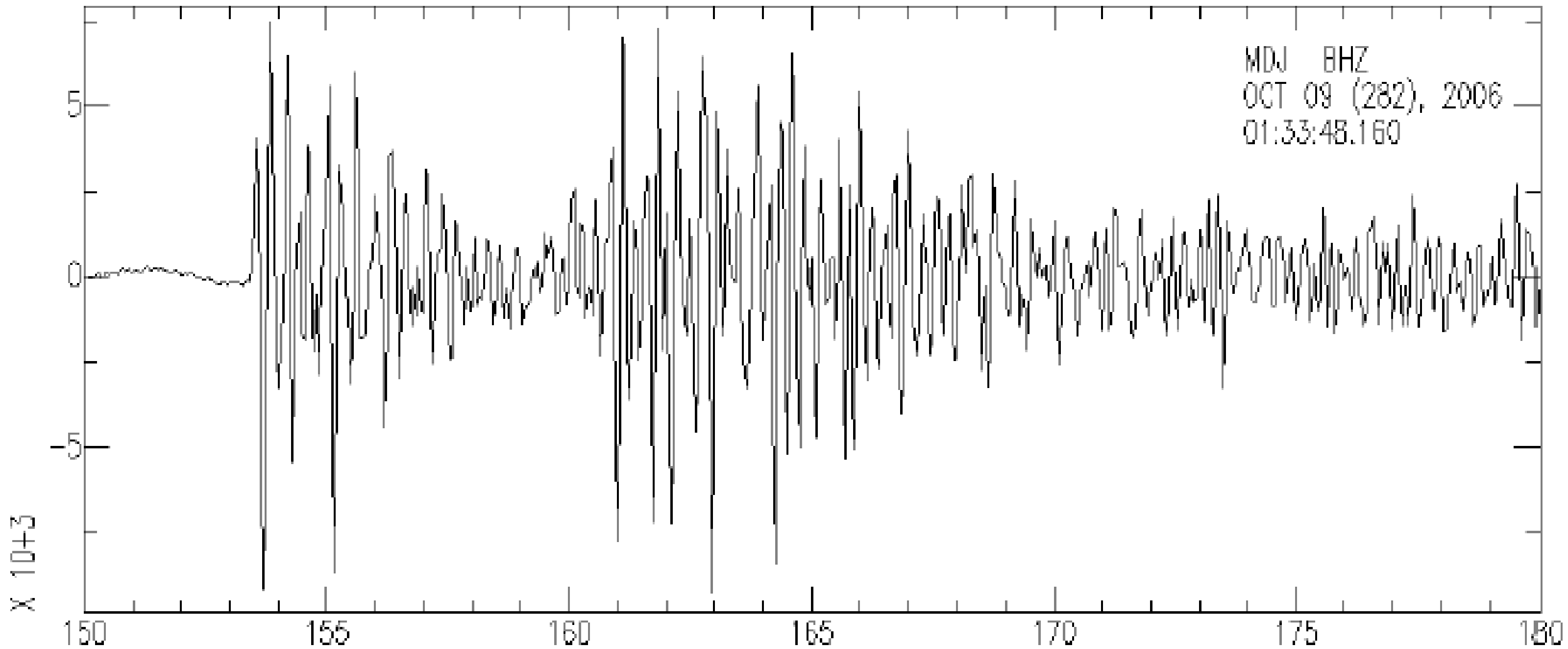
One week later, the Office of the Director of National Intelligence confirmed detection of radioactive debris and stated that North Korea had conducted a nuclear explosion with a yield of less than 1 kiloton

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

Seismic Detection of North Korea’s 2006 Nuclear Test



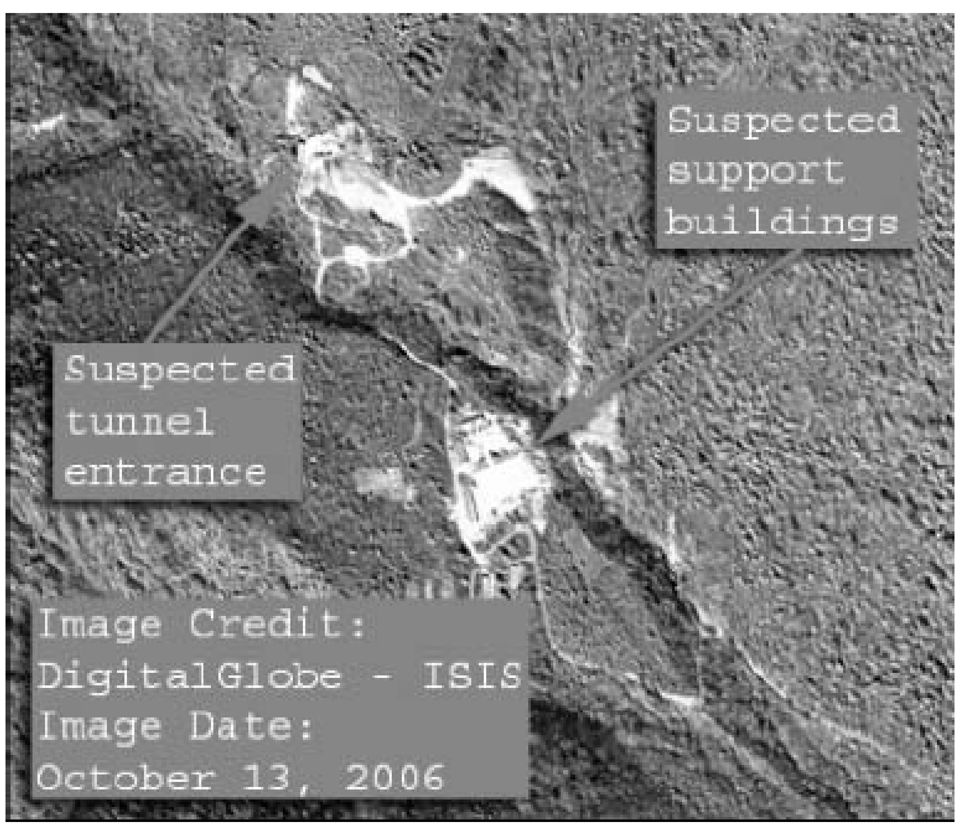


Figure 3: Satellite imagery of the suspected test site (location 41.28 N 129.08 E)[14]

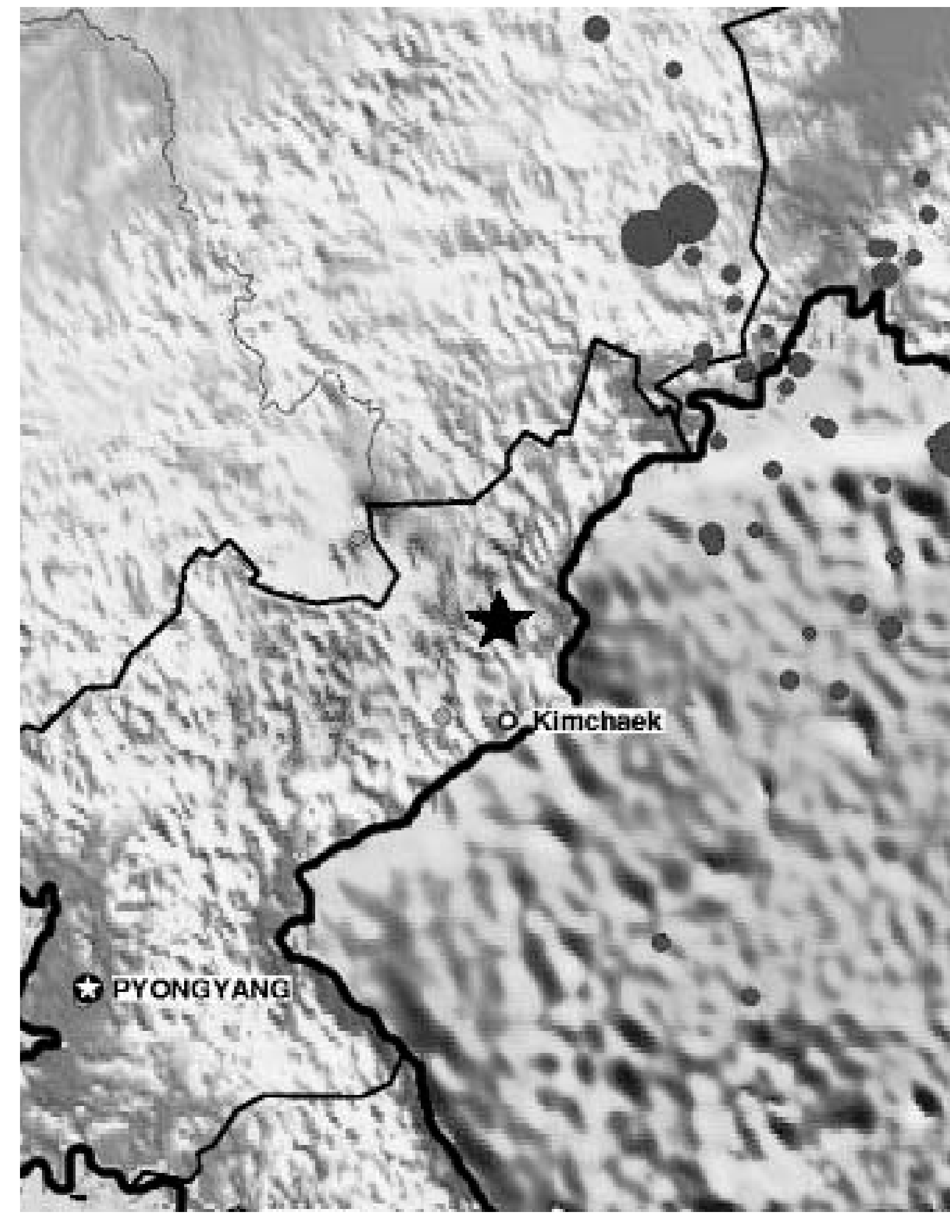


Figure 2: Seismic activity since 1990; the star shows the location of the North Korean nuclear test explosion
Source: United States Geological Survey (USGS) – National Earthquake Information Center (NEIC)

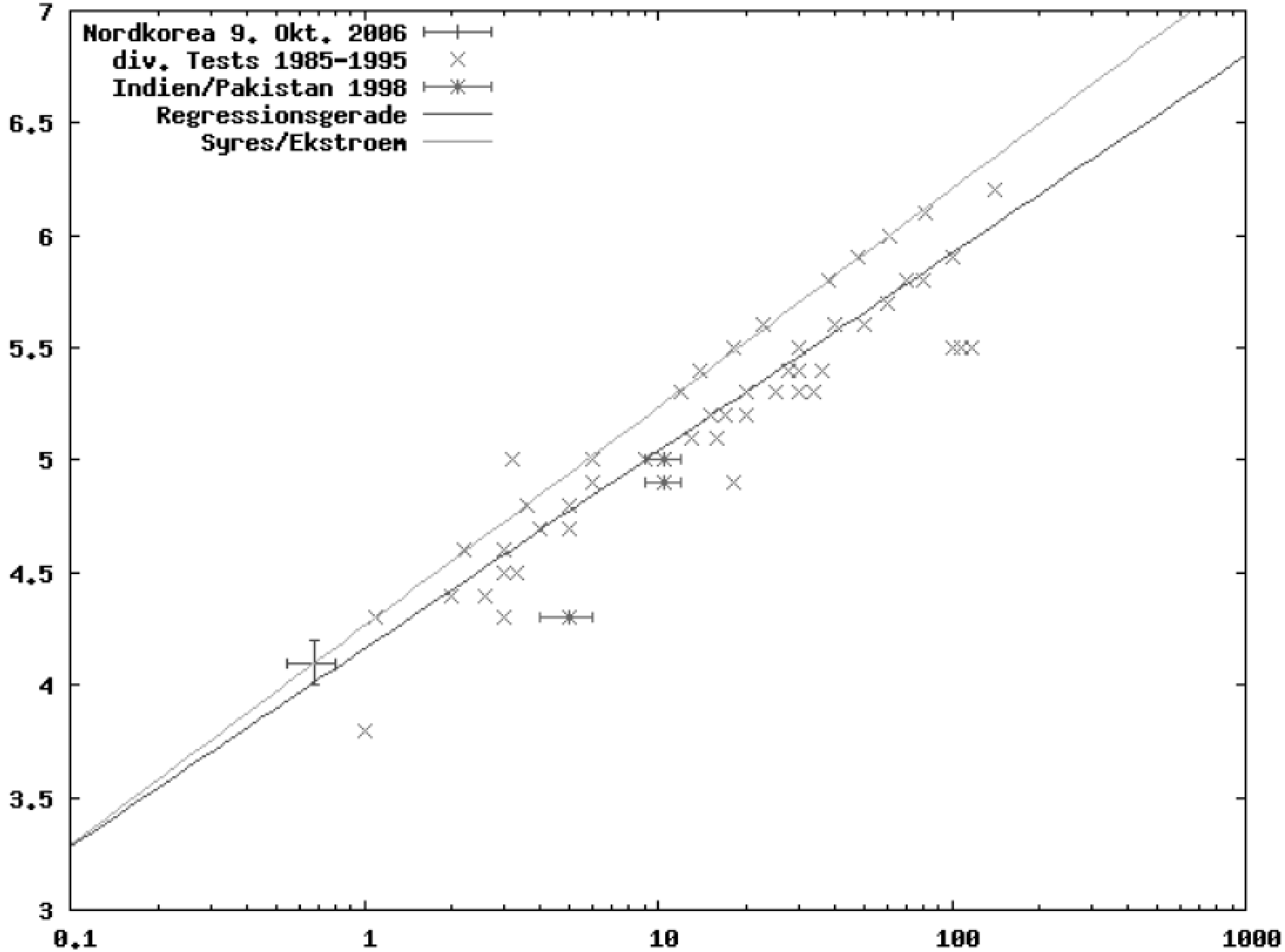
Source: Martin B. Kalinowski, Ole Ross, Analysis and Interpretation of the North Korean Nuclear Test, INESAP Information Bulletin No. 27, Dec. 2006

Comparison of Seismic Analyses 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

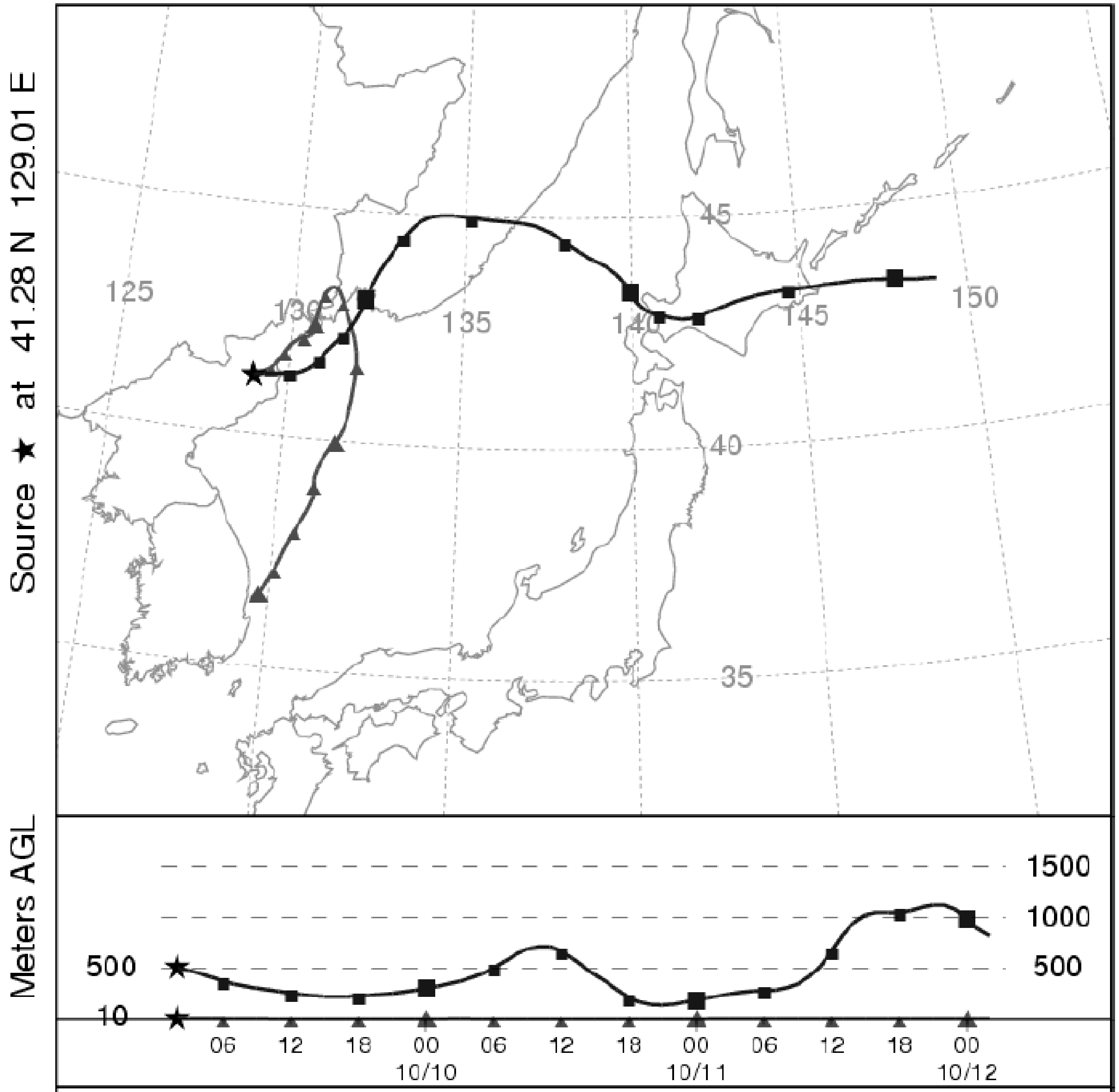
Source: Martin B. Kalinowski, Ole Ross, Analysis and Interpretation of the North Korean Nuclear Test, INESAP Information Bulletin No. 27, Dec. 2006

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



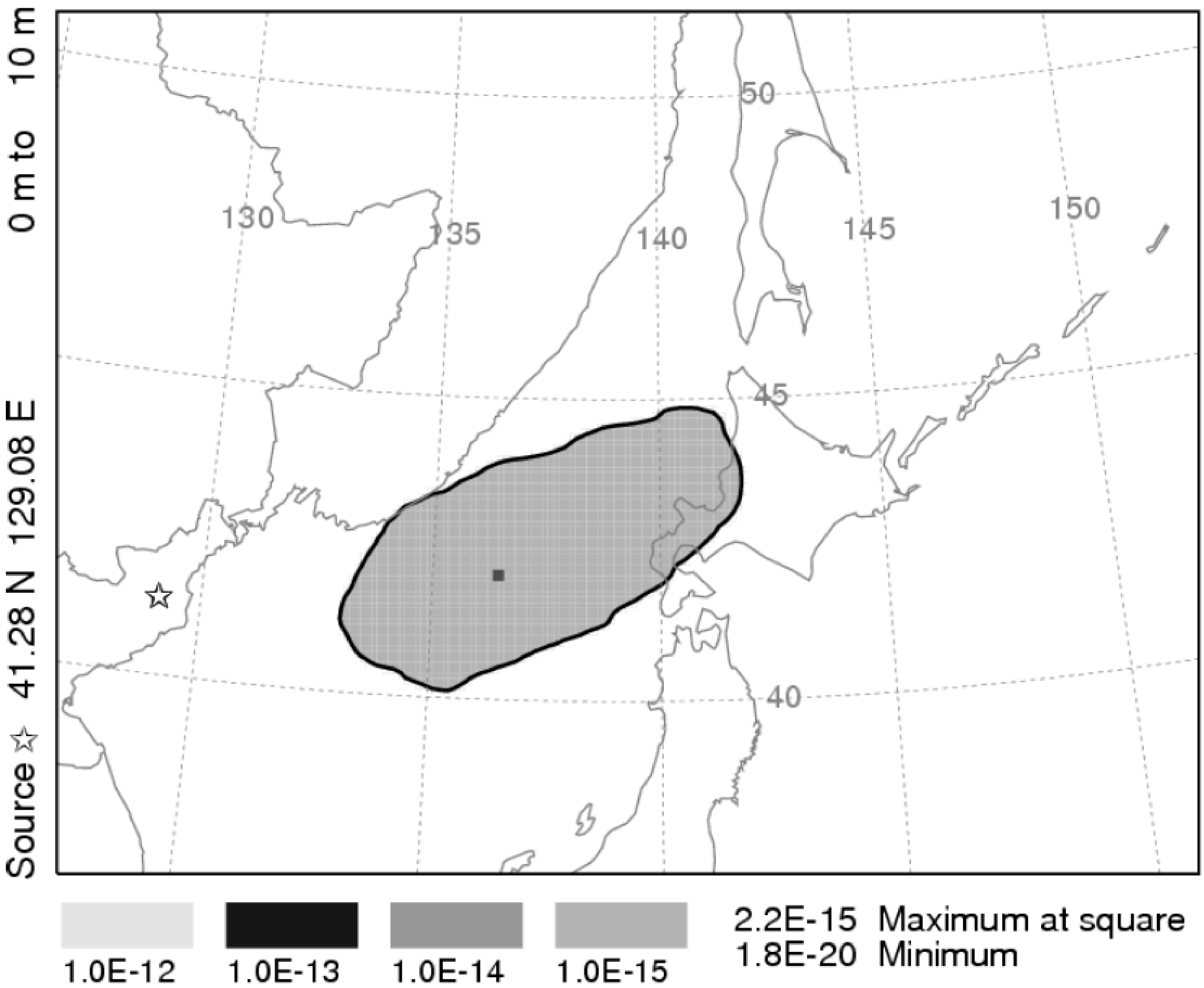
Source: Martin B. Kalinowski, Ole Ross, Analysis and Interpretation of the North Korean Nuclear Test, INESAP Information Bulletin No. 27, Dec. 2006

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 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

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

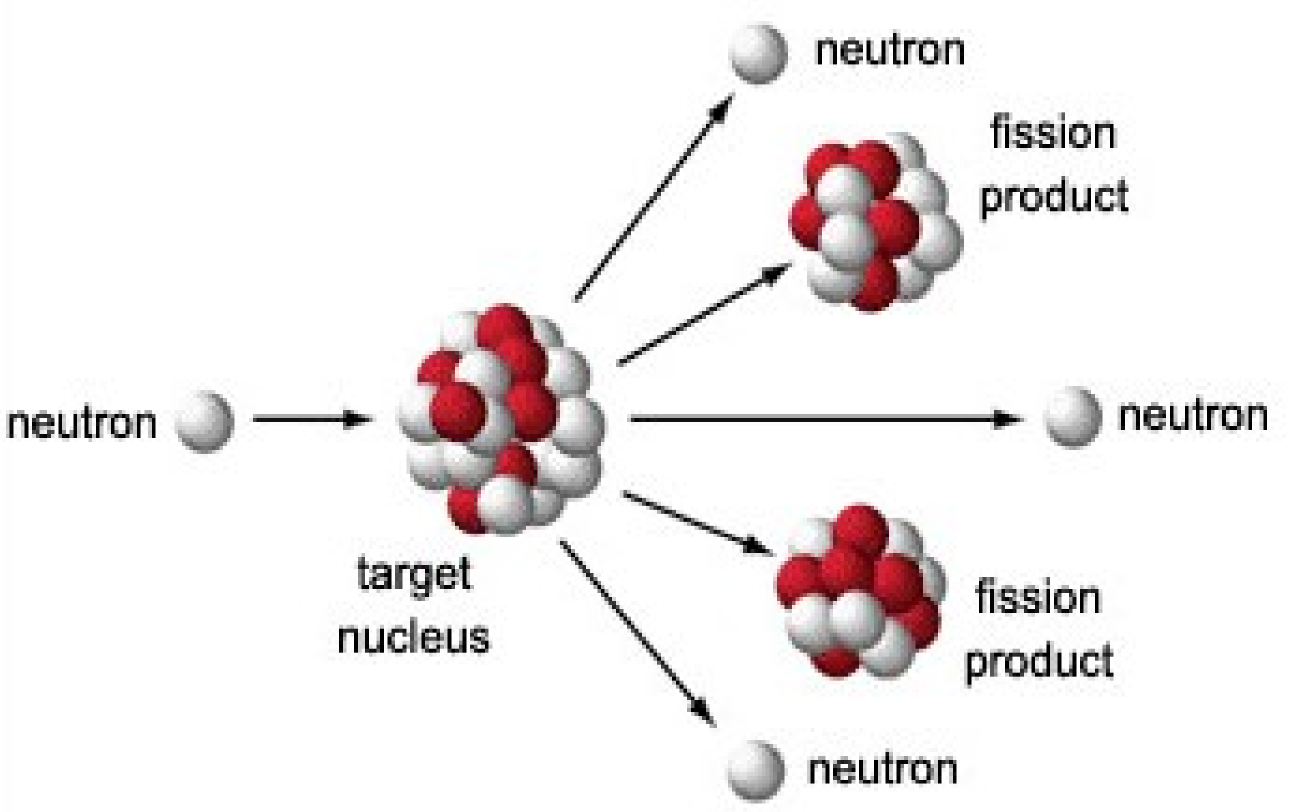
Radioactivity was detected in the atmosphere of the region two days after the explosion

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

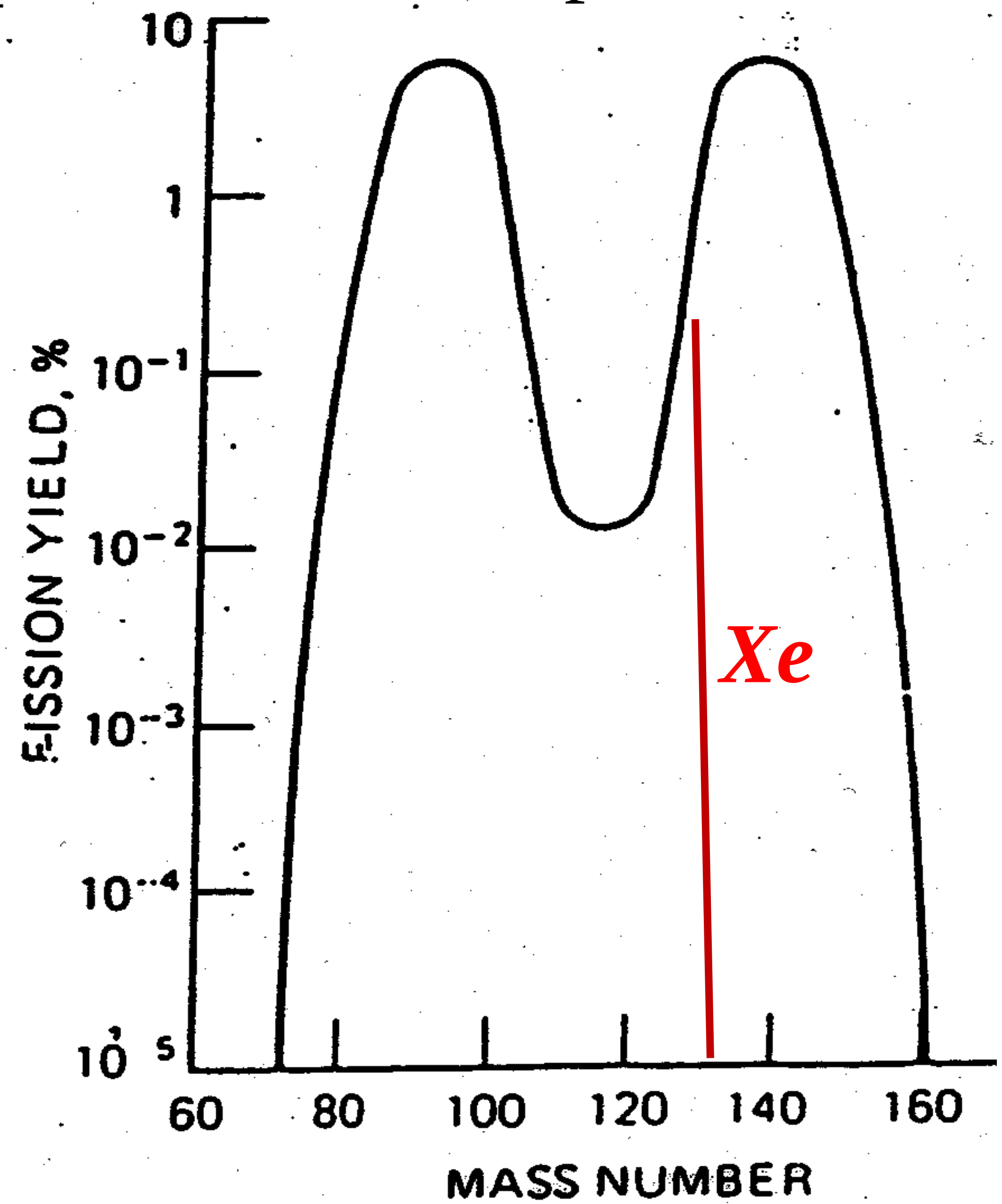
Detection of radioactive xenon isotopes, Xe-133 and Xe-135 (half-lives 5 five days, 0.4 days) indicate an underground nuclear test

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

Re-Call Distribution of Fission Fragment Masses



Mass number distribution of fission products



The fission products of neutron induced fission are nuclei with different Mass number A, including the Xenon Isotopes ^{135}Xe, ^{133}Xe, ^{131m}Xe

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, due to limitations in design and implementation of implosion technology.

2013, CTBTO Detects Fission Products from North Korean Nuclear Weapsons Test

CTBTO DETECTS RADIOACTIVITY CONSISTENT WITH 12 FEBRUARY ANNOUNCED NORTH KOREAN NUCLEAR TEST

Vienna, 23 April 2013

The CTBTO's radionuclide network has made a significant detection of radioactive noble gases that could be attributed to the nuclear test announced by the Democratic People's Republic of Korea (DPRK) on 12 February 2013.

The detection was made at the radionuclide station in Takasaki, Japan, located at around 1,000 kilometres, or 620 miles, from the DPRK test site. Lower levels were picked up at another station in Ussuriysk, Russia. Two radioactive isotopes of the noble gas xenon were identified, xenon-131m and xenon-133, which provide reliable information on the nuclear nature of the source.

The ratio of the detected xenon isotopes is consistent with a nuclear fission event occurring more than 50 days before the detection (nuclear fission can occur in both nuclear explosions and nuclear energy production). This coincides very well with announced nuclear test by the DPRK that occurred on 12 February 2013, 55 days before the measurement.

Xenon is a noble gas that cannot be chemically bound and slowly works its way out to the surface of an underground test site.

The depth of the recent DPRK test site has been estimated as 2 km at the CTBTO workshop in Urbana in April 2013.

II) 2001–2009:

Nuclear Arms Control in the Present Era: Bush II

Bush II Nuclear Arms Control

—Abandoned the ABM Treaty as not in US interests

—Abandoned the START II

—Treaty on Strategic Offensive Reductions (SORT)

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, 2016
- It would expire Dec 31, 2016 (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

Nuclear Arms Control Eras

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

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

➔Concrete steps (1) New START

(2) Nuclear Security Summit

New START

- Replaces SORT to expire December 2016

Initial Meeting between Presidents Obama and Medvedev in April 2009 in London.

Negotiations during 2009:
First round: 19–20 May, Moscow
Second round: 1–3 June, Geneva
Third round: 22–24 June, Geneva
Fourth round: 22–24 July, Geneva
Fifth Round: 5–7 September, Geneva
Sixth round: 21–28 September, Geneva
Seventh round: 19–30 October, Geneva
Eighth round: 9 November, Geneva

Signed by Presidents Obama and Medvedev in April 8th, 2010.

New START In Force Feb-5 2011

- Replaces SORT to expire December 2016

- Signed April-8-2010 (President's Obama and Medvedev)
- Ratified by Senate 12-22-2010, Duma 1-26-2011
- Entered into force February 5th 2011
- Implementation deadline February 5th 2018
- Duration February 5th 2021

- Limits deployed strategic warheads to 1550

- Limits strategic delivery vehicles to 800 with up to 700 deployed

- Verification methods: national technical means, site inspections, data exchange, notification protocols with regards to monitored sites

The Dangers of Nuclear Proliferation

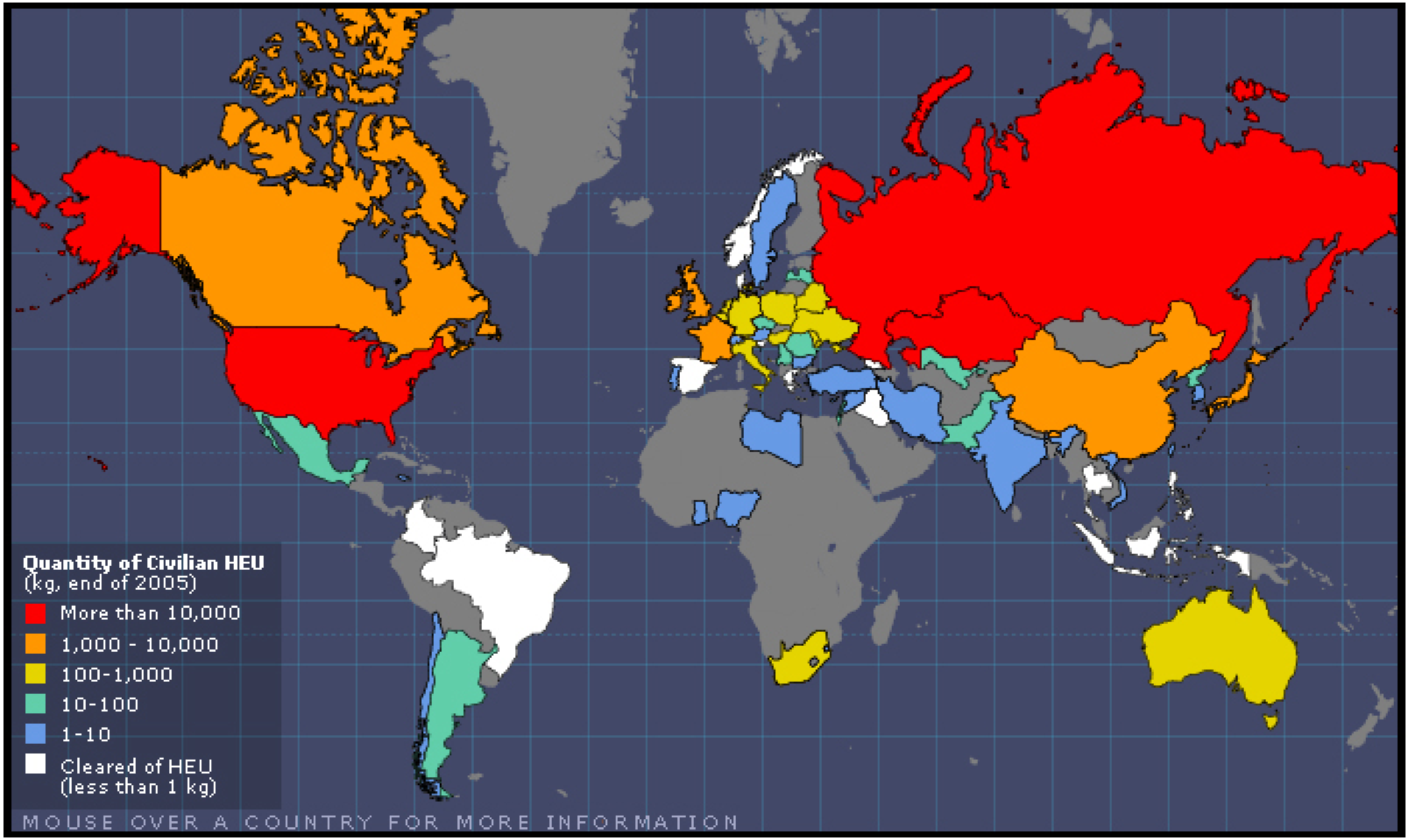
- Governments unfriendly to the U.S. are increasingly trading with one another to obtain nuclear weapons
- Nuclear weapon materials and technology have been proliferated by private networks, like the A.Q. Khan network based in Pakistan
- Theft, diversion, and sale of nuclear materials and technologies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

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

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.

Delivery Methods Other Than Long-Range Ballistic Missiles Result in Significant Threat to US National Security from Proliferation of NEM

Several countries are capable of developing mechanisms to launch SRBMs, MRBMs, or land-attack cruise missiles from forward-based ships or other platforms.

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 2016

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.

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 leads to several challenges:

- The IAEA must be able to perform it's mission to detect Significant Quantities of NEM (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 (example: North Korea).

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 significant 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

BEFORE: 20 SEP 02

AFTER: 20 JUN 04

Nuclear Safeguards

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. SQs include losses during manufacturing.

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

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.

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)

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

Nondestructive Assay (NDA)

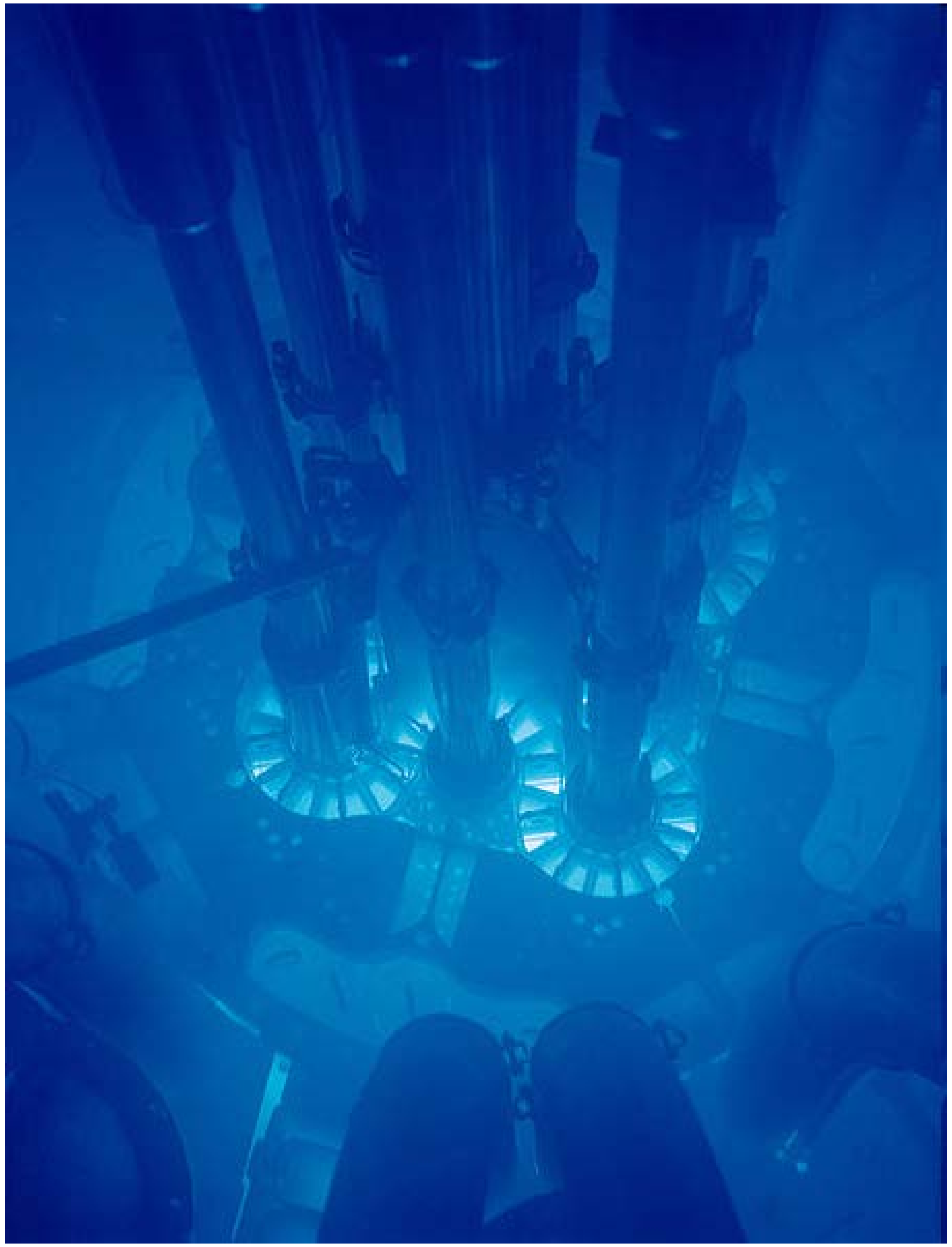
NDA tools can consist of any measurement device that does not destroy the sample.

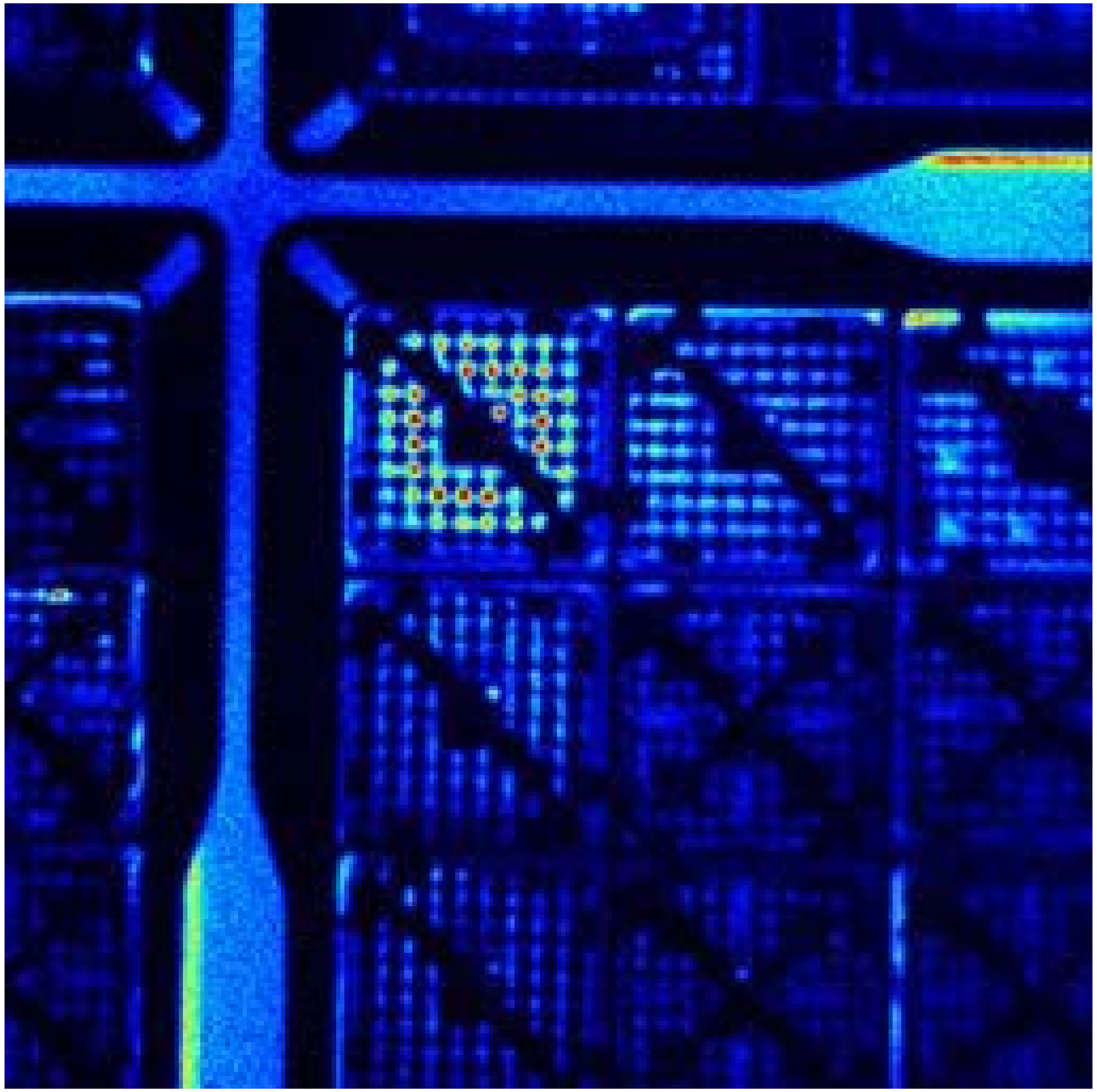
- Mass scales
- Radiation detectors/neutron counters
- Cherenkov radiation viewing devices

Advantages:

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

Cherenkov Radiation





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

Destructive Analysis (DA)

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

- Mass spectrometry
- Chemical analysis
- Radiochemical analysis

Advantages:

- More precise than NDA measurements
- Lower detections limits

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

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.

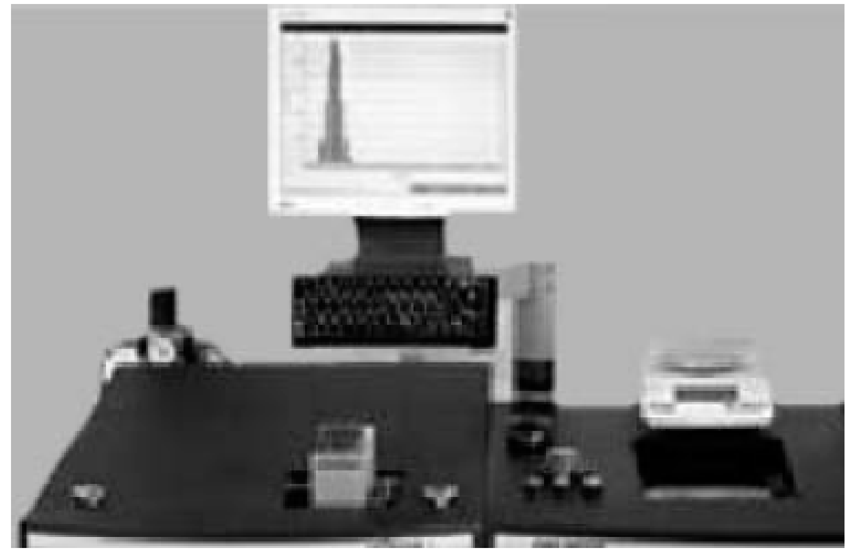


Figure 11: Basic Methodology 2
Samples are brought to a field laboratory for analysis.

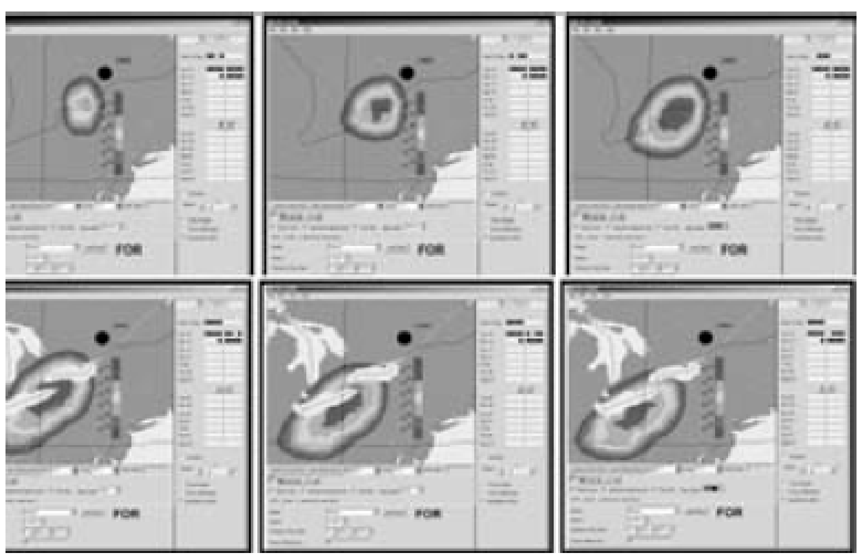


Figure 12: Basic Methodology 3
The sample analysis data is combined with meteorological data and suitable atmospheric modelling to provide an estimate of the source direction.

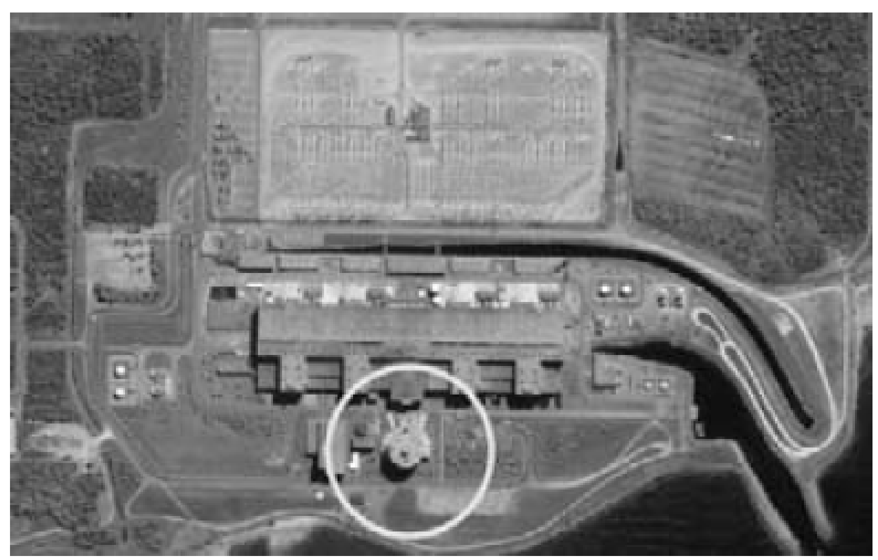


Figure 13: Basic Methodology 4
The airborne material is identified and the probable location of the source is estimated.

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

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

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

Solution:

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

Laser-Induced Breakdown Spectroscopy (LIBS)

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

Application: both on-site and off-site analysis.

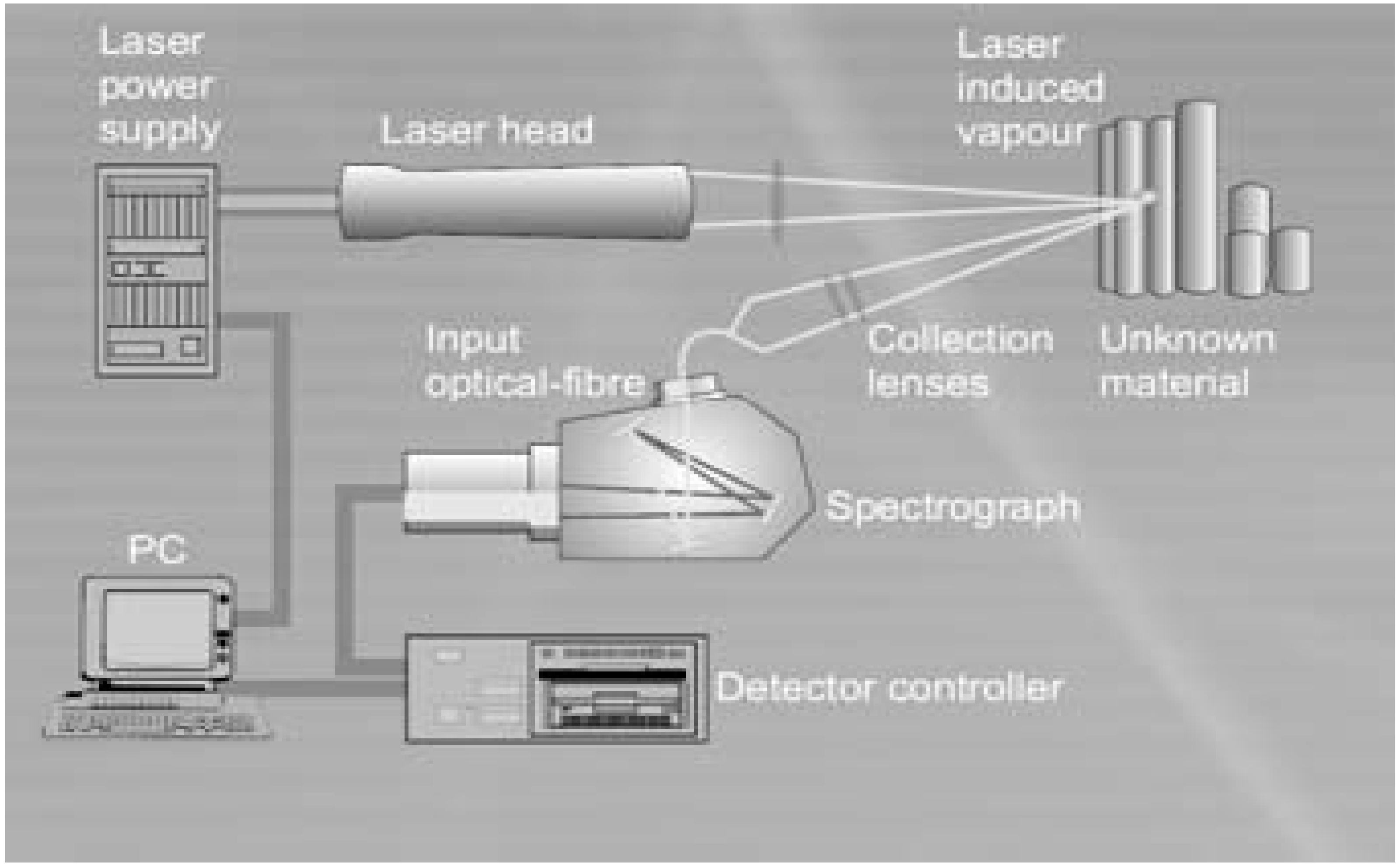


Figure 6: Basic Methodology 2
LIBS is comprised of (i) a laser system to ablate the surface of the material to be analyzed to create a micro-vapour, and (ii) a spectrometer to generate a spectroscopic profile of the micro-vapour's constituent components.

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

Material Unaccounted for, 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 measurements to quantify the amount of nuclear material in the facility.

All measurements have errors !!

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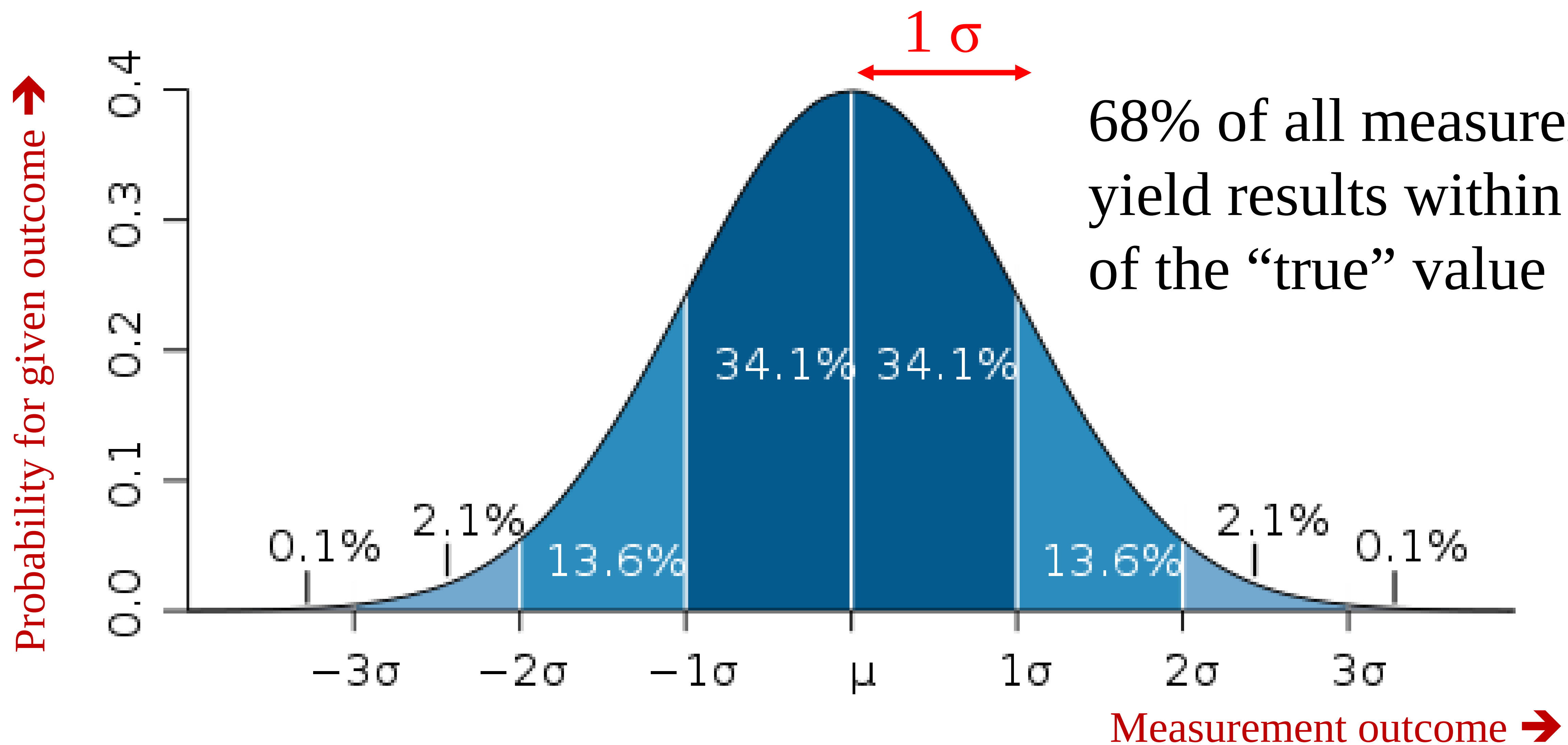
Distribution and Probabilities of Measurement Results



68% of all measurements yield results within 1 σ of the "true" value

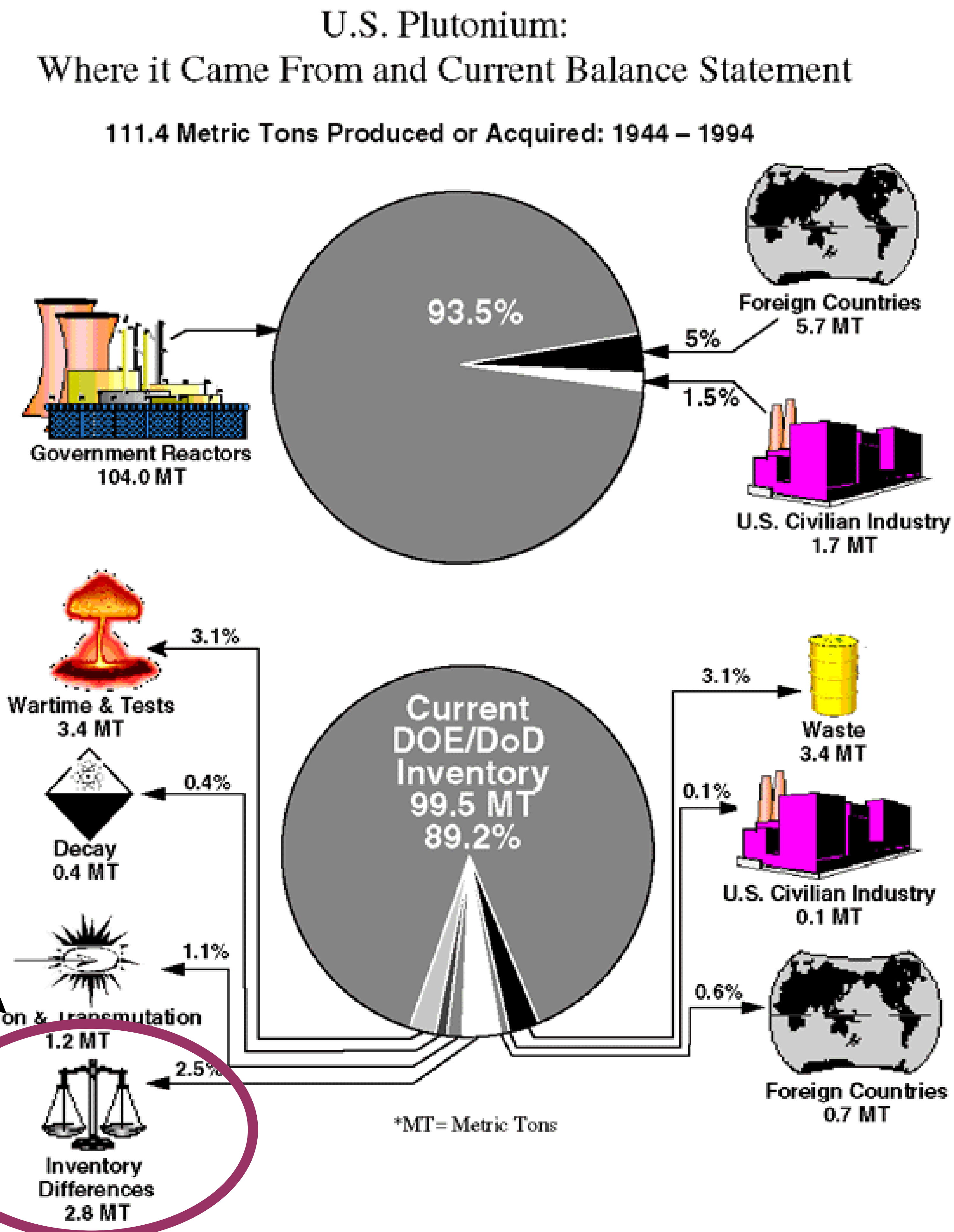
Ref: "Standard Deviation"

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

Problem with accountancy at bulk material facilities

MUF = **M**aterial
Unaccounted **F**or

The problem of bulk material accountancy.



End of Module

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*.

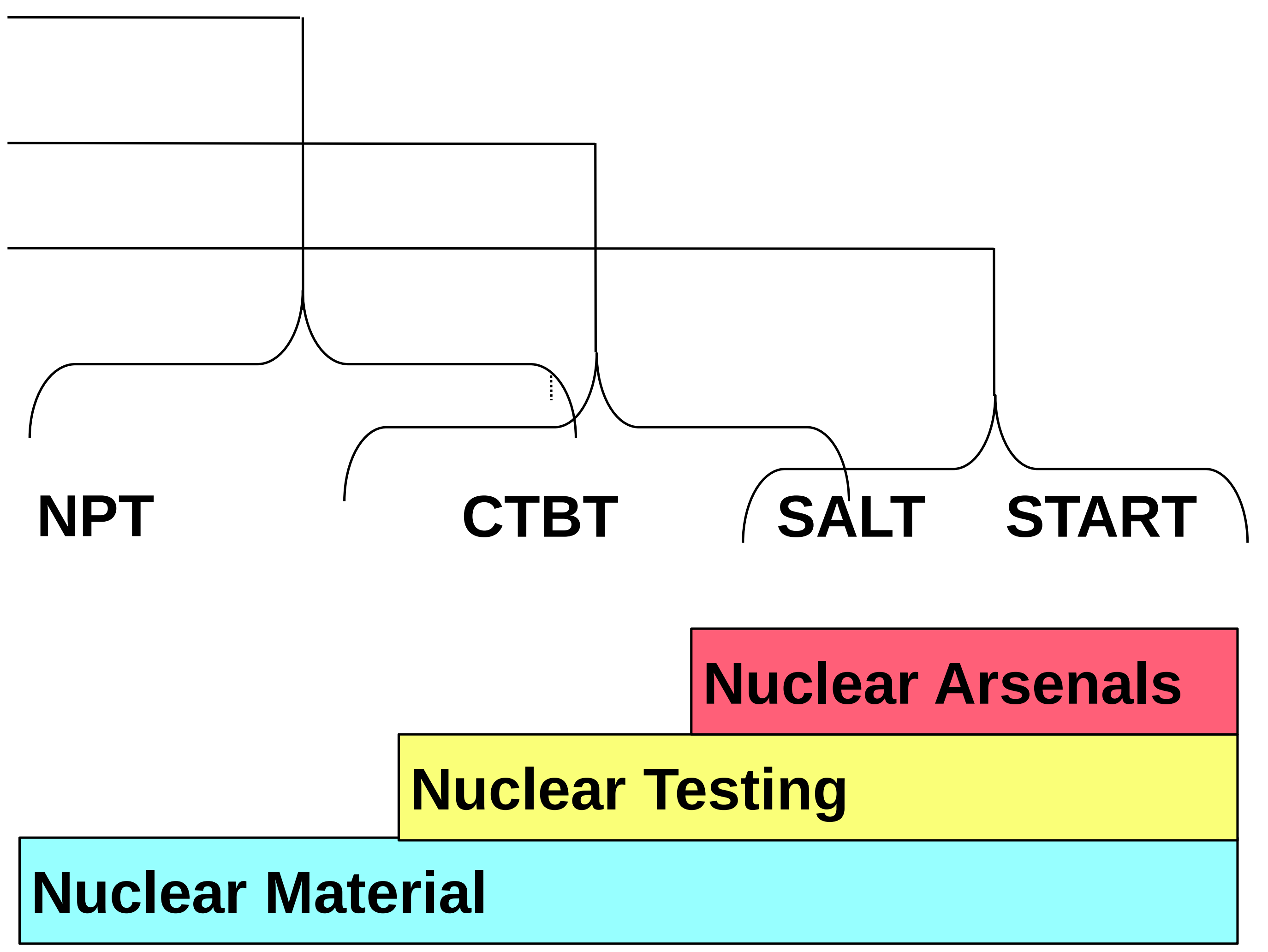
Goals of Nuclear Arms Control

Examples of major nuclear arms control agreements

Horizontal non-proliferation

Vertical non-proliferation

Disarmament



Goals of Nuclear Arms Control

Success story

The NPT is the central treaty of nuclear non-proliferation regime

Number of State-Parties to the NPT

1970:	43
1975:	96
1985:	132
1995:	182
2005:	189 of 193 sovereign UN member states

(Israel, India, Pakistan, and North Korea are not parties)

An Explanation of the Language Used in National Intelligence Estimates – 1

From the November 2007 NIE "Iran: Nuclear Intentions and Capabilities

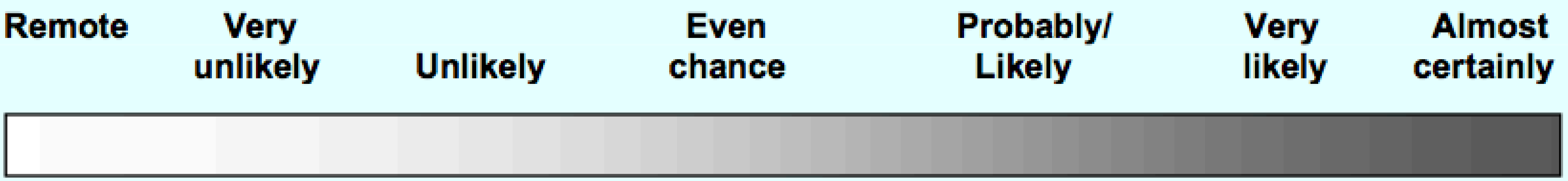
What We Mean When We Say: An Explanation of Estimative Language

We use phrases such as *we judge, we assess,* and *we estimate*—and probabilistic terms such as *probably* and *likely*—to convey analytical assessments and judgments. Such statements are not facts, proof, or knowledge. These assessments and judgments generally are based on collected information, which often is incomplete or fragmentary. Some assessments are built on previous judgments. In all cases, assessments and judgments are not intended to imply that we have "proof" that shows something to be a fact or that definitively links two items or issues.

In addition to conveying judgments rather than certainty, our estimative language also often conveys 1) our assessed likelihood or probability of an event; and 2) the level of confidence we ascribe to the judgment.

An Explanation of the Language Used in National Intelligence Estimates – 2

Estimates of Likelihood. Because analytical judgments are not certain, we use probabilistic language to reflect the Community's estimates of the likelihood of developments or events. Terms such as *probably*, *likely, very likely,* or *almost certainly* indicate a greater than even chance. The terms *unlikely* and *remote* indicate a less then even chance that an event will occur; they do not imply that an event will not occur. Terms such as *might* or *may* reflect situations in which we are unable to assess the likelihood, generally because relevant information is unavailable, sketchy, or fragmented. Terms such as *we cannot dismiss, we cannot rule out,* or *we cannot discount* reflect an unlikely, improbable, or remote event whose consequences are such that it warrants mentioning. The chart provides a rough idea of the relationship of some of these terms to each other.



An Explanation of the Language Used in National Intelligence Estimates – 3

Confidence in Assessments. Our assessments and estimates are supported by information that varies in scope, quality and sourcing. Consequently, we ascribe *high*, *moderate*, or *low* levels of confidence to our assessments, as follows:

- *High confidence* generally indicates that our judgments are based on high-quality information, and/or that the nature of the issue makes it possible to render a solid judgment. A "high confidence" judgment is not a fact or a certainty, however, and such judgments still carry a risk of being wrong.

- *Moderate confidence* generally means that the information is credibly sourced and plausible but not of sufficient quality or corroborated sufficiently to warrant a higher level of confidence.

- *Low confidence* generally means that the information's credibility and/or plausibility is questionable, or that the information is too fragmented or poorly corroborated to make solid analytic inferences, or that we have significant concerns or problems with the sources.

New START Nuclear Force Levels – U.S.

The United States (UPDATED 02/29/10)

	July 2009 Old START	2010 Actual operationally deployed launches (total launchers)	ca. 2020 New START operationally deployed launchers (total launchers) [estimate]	ca. 2020 New START warheads [estimate]
ICBMs				
Minuteman III	500	450	350	350
MX	50	0		
Total ICBMs	**550**	**450**	**350**	**350**

New START Nuclear Force Levels – U.S.

SLBMs				
Trident I/C-4	4/96			
Trident II/D-5	14/336	12/288 (14/336)	12/288 (14/336)	1152
Total SLBMs	**268**	**288 (336)**	**288 (336)**	**1152**
Bombers				
B-1	47	0		
B-2	18	16 (18)	16 (18)	16
B-52	141	44 (93)	32 (93)	32
Total bombers	**206**	**60 (111)**	**48 (111)**	**48**
TOTAL	**1188**	**798 (897)**	**686 (797)**	**1550**

New START Nuclear Force Levels – Russia

Russia

	July 2009 Old START	2010 Actual operationally deployed launches (total launchers)	ca. 2020 New START operationally deployed launchers (total launchers) [estimate]	ca. 2020 New START warheads [estimate]
ICBMs				
SS-25	176	171		
SS-27 silo	50	50	60	60
SS-27 road	15	18	27	27
RS-24			85	255
SS-19	120	70		
SS-18	104	59	20	200
Total ICBMs	**465**	**367**	**192**	**542**

New START Nuclear Force Levels – Russia

SLBMs				
Delta III/SS-N-18	6/96	4/64		
Delta IV/SS-N-23	6/96	4/64 (6/96)	4/64	256
Typhoon/SS-N-20	2/40	0/0		
Borey/Bulava	2/36	0/0	4/64	384
Total SLBMs	**268**	**128 (164)**	**128**	**640**
Bombers				
Tu-160	13	13	13	13
Tu-95MS	63	63	63	63
Total bombers	**76**	**76**	**76**	**76**
TOTAL	**809**	**571 (603)**	**396 (396)**	**1258**

http://allthingsnuclear.org/tagged/by-David-Wright

Physics/Global Studies 280: Final

The **final exam** will take place on

Thursday May 14th from 8-11am
Location will be announced by e-mail.

Scope of exam:

120 multi-choice problems
70 questions on arsenals, defenses, arms control + news
50 questions on material covered before midterm

50% of the questions will be taken from the final exams of the last 3 years (available from the course web-page)

Suggestions for Final Prep

(1) Study old final exams and use slides + posted reading assignments to verify your answers.

(2) Review all news discussed in class.

(3) Bring questions to review session.

(4) Review course slides.

(5) Review reading materials.

Physics 280: Session 26

Questions

Module 8: Nuclear Arms Control cont'd