Physics 280: Session 25

Announcement

Final Exam Review Session

Student questions

News and discussion

Module 8: Nuclear Arms Control

ACIDS Spring Seminar Series

Picturing the Bomb: Film and the Production of Nuclear Weapons in Cold War America

Kevin Hamilton
School of Art + Design
UIUC

– and –

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Friday • April 20 • 12:00 PM
356 Armory
505 East Armory Ave

Physics 280: Final Exam Review Session

Final Exam Review Session

Thursday, May 3rd

(A) 6.30pm

(B) 7.00pm

(C) 7.30pm

News and Discussion

North Korea: Failed Rocket Launch, Friday April 13

Washington Post April 8th:

North Korea arranges for foreign journalists to visit Unha-3 launch pad

News and Discussion

North Korea:
Failed Rocket Launch,
Friday April 13

The Washington Post

North Korea reports failure of launch in its own state media

In a first, North Korea tells its people about a failure

By Chico Harlan, Published: April 13

SEOUL — North Korea has long been better at making myths than making rockets, but it showed a new face on Friday in acknowledging the failure of the country's third effort to blast a satellite into space.

The launch required the impoverished North to spend hundreds of millions of dollars, according to estimates — an investment it hoped to use to build national pride and support for new leader Kim Jong Eun, analysts say.

"This a very sensitive time for Kim Jong Eun's leadership," said Ryoo Kihl-jae of Seoul's University of North Korean Studies. "You won't see protests because of this. But it can introduce an element of doubt" about his ability.

"Scientists, technicians and experts are now looking into the cause of the failure," the broadcaster told viewers.

News and Discussion

The Washington Post

U.N. condemns North Korean rocket launch, stops short of penalties

By William Wan and Colum

Looming over any diplomatic response is the possibility of North Korea's third nuclear test.

Even before the latest rocket launch, the South Korean government had warned that the North might be preparing for such a test, citing satellite images of accumulating mounds of dirt at a location used for underground tests in 2006 and 2009. U.S. intelligence analysts have said they are also studying the location intently.

"The dirt pile is clearly visible," said Paul Brannan, a nonproliferation analyst at the Institute for Science and International Security, who has obtained and studied the same satellite image used by the South Koreans. "And it follows the North's previous patterns of missile test then nuclear test. So it does seem likely."

The difference this time is that North Korea may use highly enriched uranium rather than plutonium. A successful test would indicate a proficient uranium program, which is much easier to produce undetected.

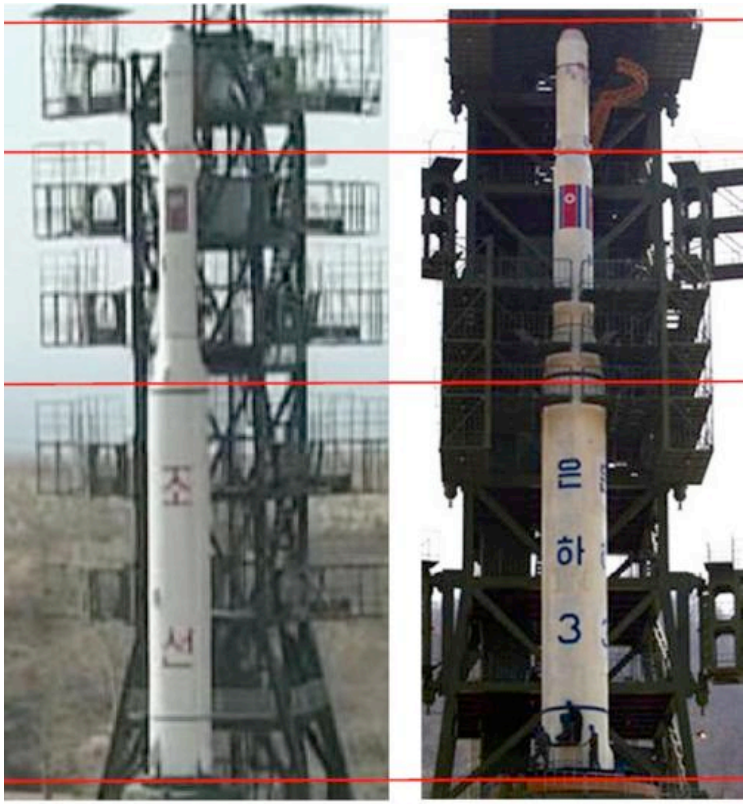
news agency.

News and Discussion

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

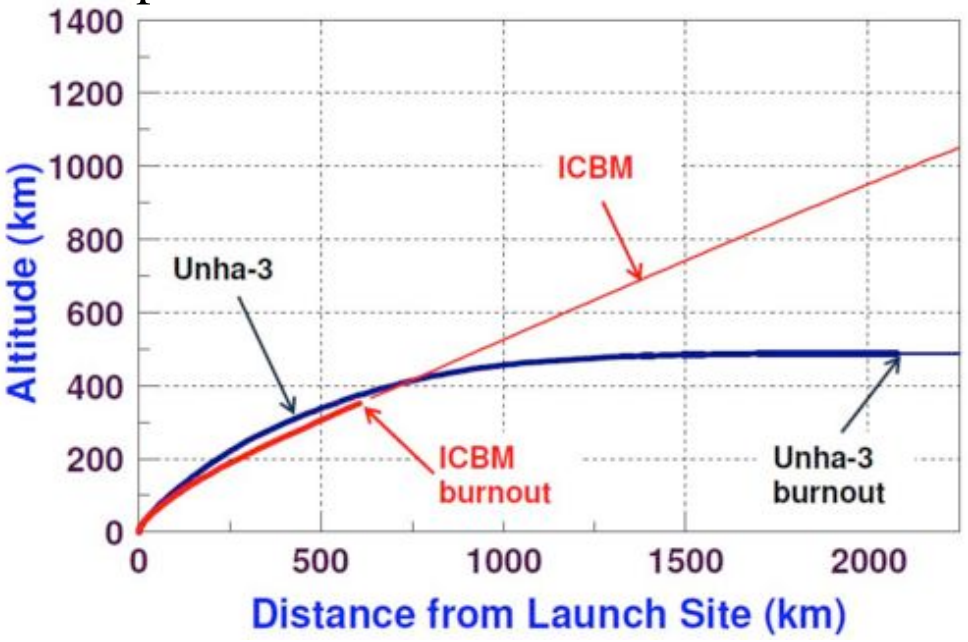
David Wright's analysis from the Union of Concerned Scientists

Rocket is very similar to Unha-2

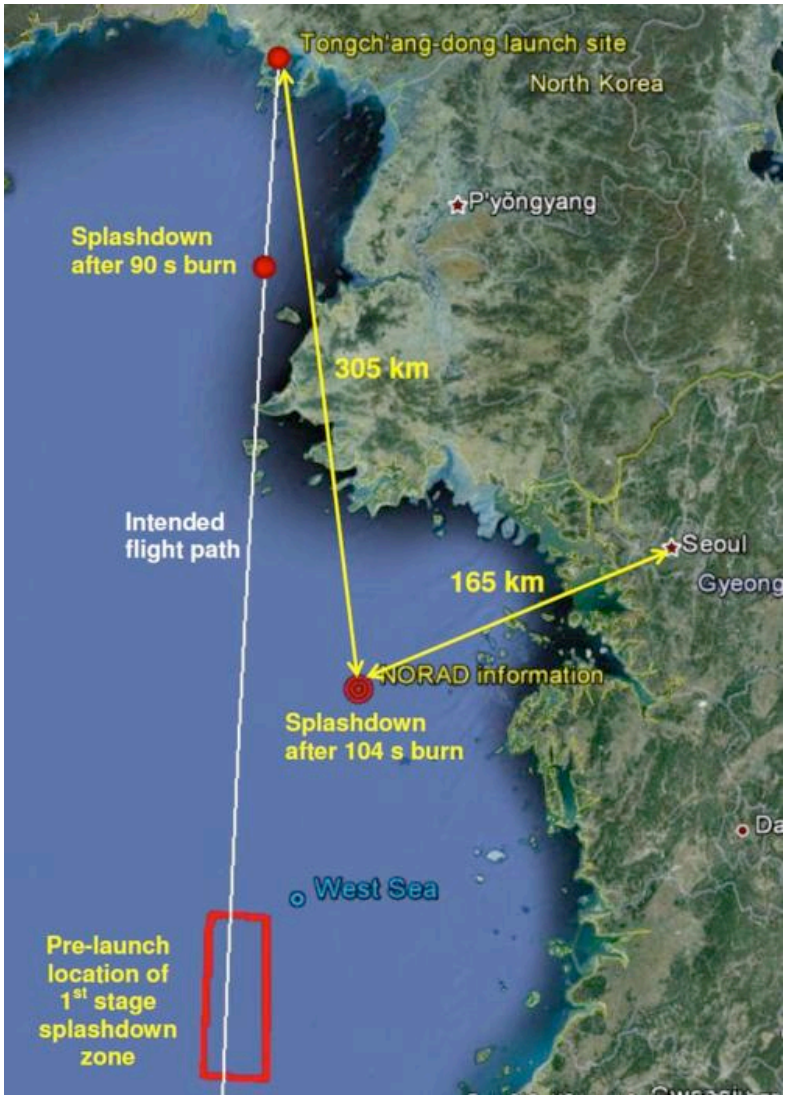


Unha-2 (April 2009) Unha-3 (April 2012)

Flight path of ICBM s vs flight path for satellite launch



News and Discussion



Analysis from David Wright, Union of Concerned Scientists

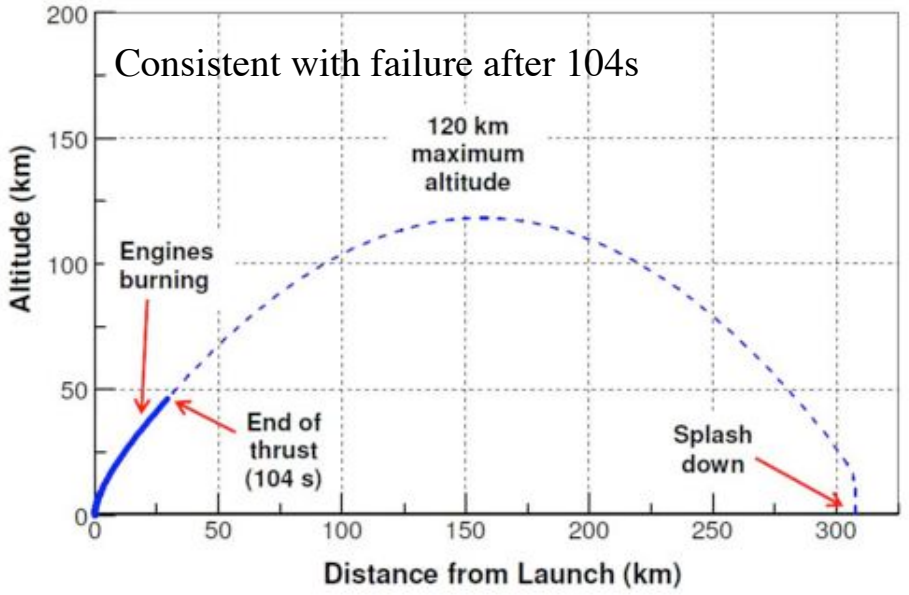
Reported facts assumed to be correct as base for analysis:

The rocket engines burned for less than two minutes before the failure

The rocket body broke into pieces and the pieces continued traveling through the atmosphere for 6 to 7 minutes

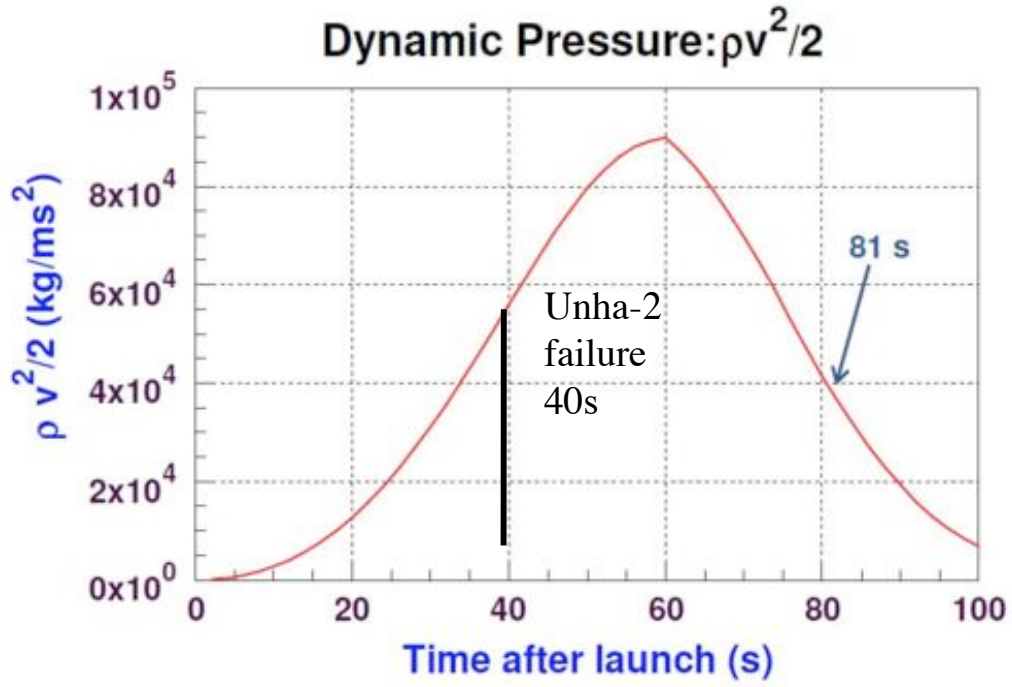
The pieces reached a maximum altitude of 120 km

The pieces splashed down in the Yellow Sea 165 km southwest of Seoul.



News and Discussion

David Wright cont'd
Highest dynamic pressures after 60s
Failure after 104s not very likely



possibility that launch may have been aborted by ground control after rocket deviated from course.

Module 8: Nuclear Arms Control

Nuclear Arms Control

Nature and Goals of Arms Control

Example for Arms Control

Arms Control in the area of chemical warfare

First treaty: the 1925 Geneva Protoco

bans the use of chemical weapons.

Current: Chemical Weapons Convention

Entered into force on April 29th 1997

Bans use & possession of chemical weapons

Defines time table for destruction of chemical weapons

(US reached 60% mark in 2009, eg. Newport, Indiana)

Duration: Indefinite

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 within legal & ethical considerations
- Other security instruments
  - — Political
  - — Economic
  - — Technological
  - — Environmental

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 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

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 individual nations and human civilization.

Nuclear Arms Control

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

Other Important Nuclear Arms Control Agreementsand 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), 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

Nuclear Arms Control

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 (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)

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 —

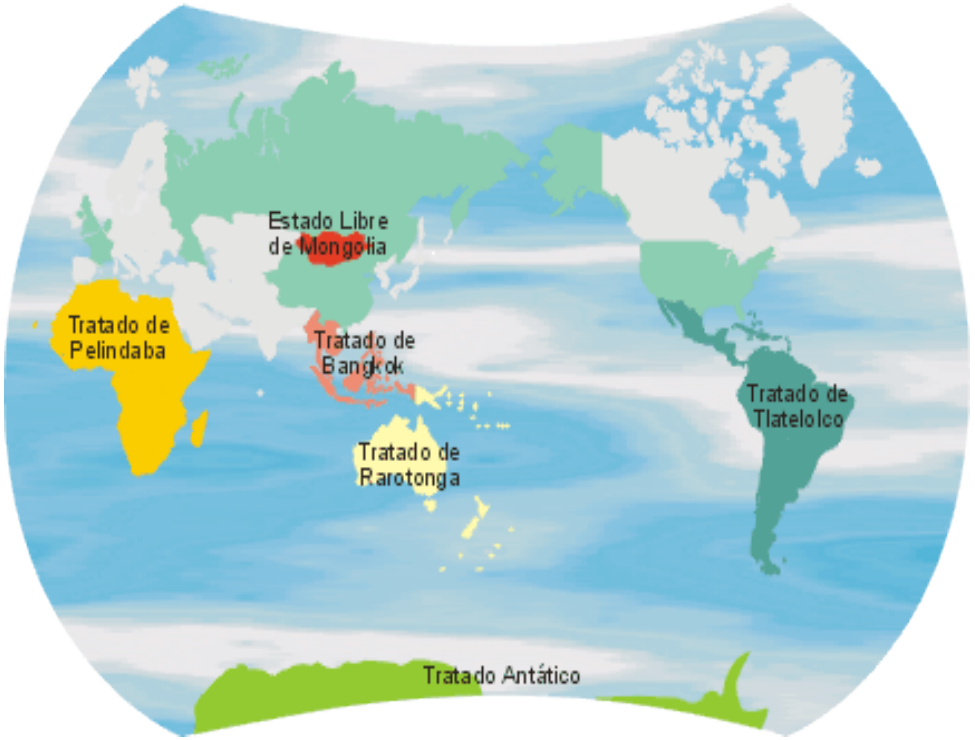
- A two-page treaty (see the PHYS-280 documents web page)
- Bans “any nuclear weapons test explosion, or any other nuclear explosion”
- “in the atmosphere; beyond its limits, including outer space; or underwater”
- “in any other environment if such explosion causes radioactive debris to be present outside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

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

Physics 280: Session 26

Questions

News and discussion

Module 8: Nuclear Arms Control

News and Discussion

North Korea: Concerns of nuclear weapon test with HEU
vs surprise over new openness of Kim Jong-Il

Too early to tell on North Korean leader: Clinton

4:52am EDT

WASHINGTON (Reuters) - Secretary of State Hillary Clinton offered some hope on Wednesday that North Korea's young leader, Kim Jong-un, may yet change course despite the reclusive Communist state's recent rocket launch and the threat of a new nuclear test.

In an interview with CNN's "The Situation Room," Clinton said it was too early to tell what to make of the surprise remarks to soldiers on Sunday by the youngest son of the late Kim Jong-il, who saw North Korea fall into deep poverty and developed a nuclear weapons program during his 17-year rule.

Without elaborating, Clinton said Jong-un's speech was analyzed as "some of the old - same old stuff" and "some possible new approach".

"We really are waiting and watching to see whether he can be the kind of leader that the North Korean people need.

Reuters

"If he just follows in the footsteps of his father, we don't expect much other than the kind of provocative behavior and the deep failure of the political and economic elite to take care of their own people," Clinton said.

"But he is someone who has lived outside of North Korea, apparently, from what we know. We believe that he may have some hope that the conditions in North Korea can change. But again we're going to watch and wait," she said.

News and Discussion

North Korea: Concerns of nuclear weapon test with HEU vs surprise over new openness of Kim Jong-Il

April 18, 2012

US Lawmakers Call for Tougher Approach to North Korea

Cindy Saine | Capitol Hill

House Foreign Affairs Committee Chairman Ileana Ros-Lehtinen of Florida says the Obama administration has fallen into the same failed pattern of negotiations with North Korea, followed by betrayal by Pyongyang, that the Bush and Clinton administrations had also pursued in vain. She says the new North Korean leader, Kim Jong Un, seems to be following in his late father Kim Jong Il's footsteps, in responding to an outstretched hand by provoking the world with last Friday's failed rocket launch.

"North Korea's rhetoric should have told our negotiators all they needed to know," said Ros-Lehtinen. "The 'military first' policy of starving the people to feed the army and supply the munitions industry remains. The South Korean Defense Ministry estimated this month that the North Koreans spent $850 million on the failed missile launch - enough to buy corn to feed the entire population for an entire year."

The lawmakers and experts present at the hearing agreed that North Korea has shown that it is indeed still dangerous and erratic. Michael Green of the Center for Strategic and International Studies says he believes we may see a North Korean nuclear test in the future.

News and Discussion

In the meantime: India uses the North Korean crisis to carry out a successful ICBM test !

India tests missile capable of reaching Beijing

By Simon Denyer, Published: April 18 | Updated: Thursday, April 19, 3:01 AM

NEW DELHI — India successfully test-launched a long-range missile on Thursday that would give it the capability of sending a nuclear warhead as far as China's capital, Beijing, for the first time, officials said.

Officials and defense experts said that the Agni-V missile marks a significant improvement in India's nuclear-deterrent capability and was clearly aimed at bolstering its defense against neighboring China.

It also puts India on the cusp of a small group of nations with intercontinental nuclear weapons capabilities, and burnishes its credentials as a global heavyweight.

"Today's successful Agni-V test launch represents another milestone in our quest to add to the credibility of our security and preparedness," Prime Minister Manmohan Singh said in a statement, while Defence Minister A.K. Anthony called it an "immaculate success."

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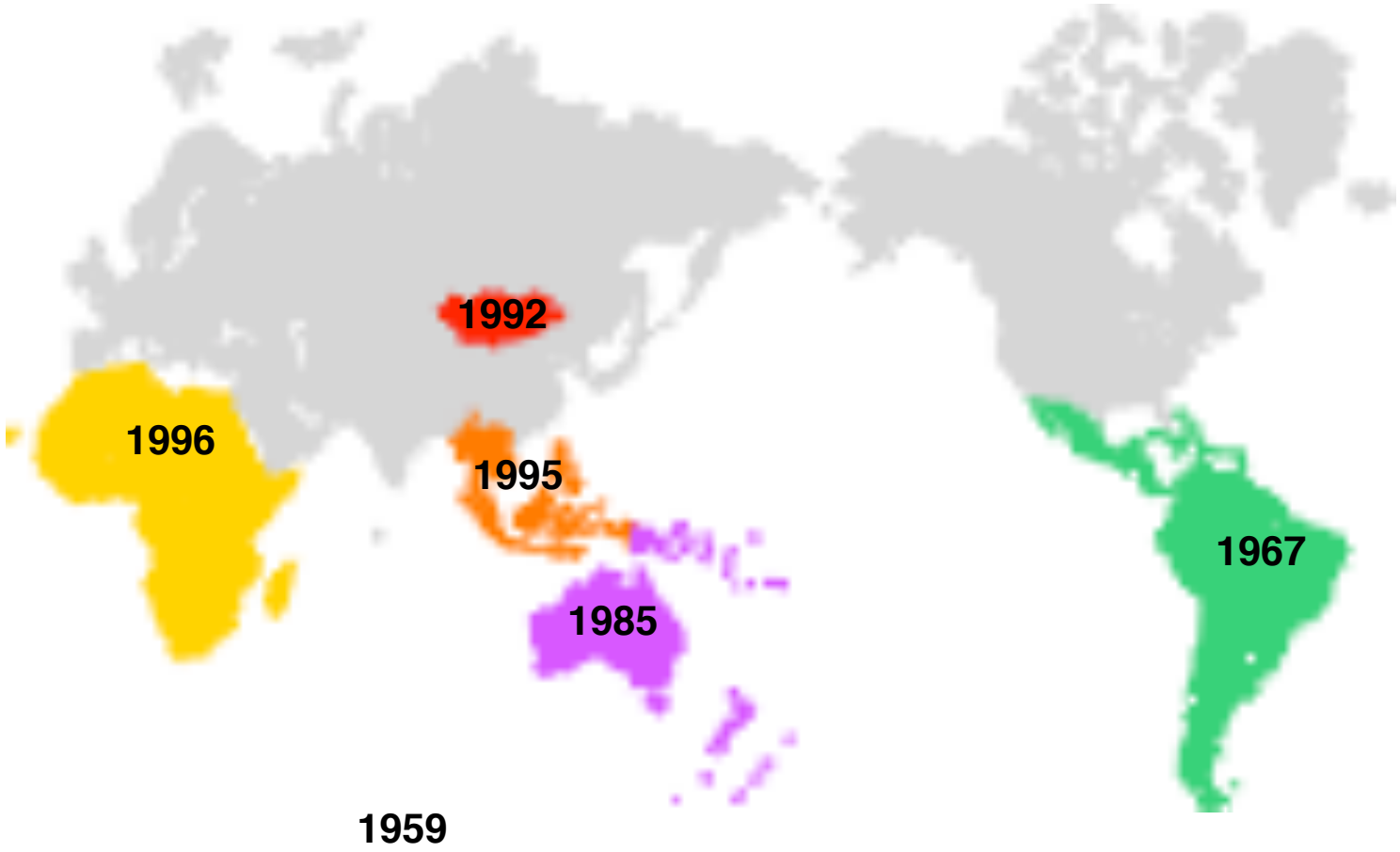
l also bolsters its

Nuclear-Weapon-Free Zones

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



Nuclear-Weapon-Free Zones

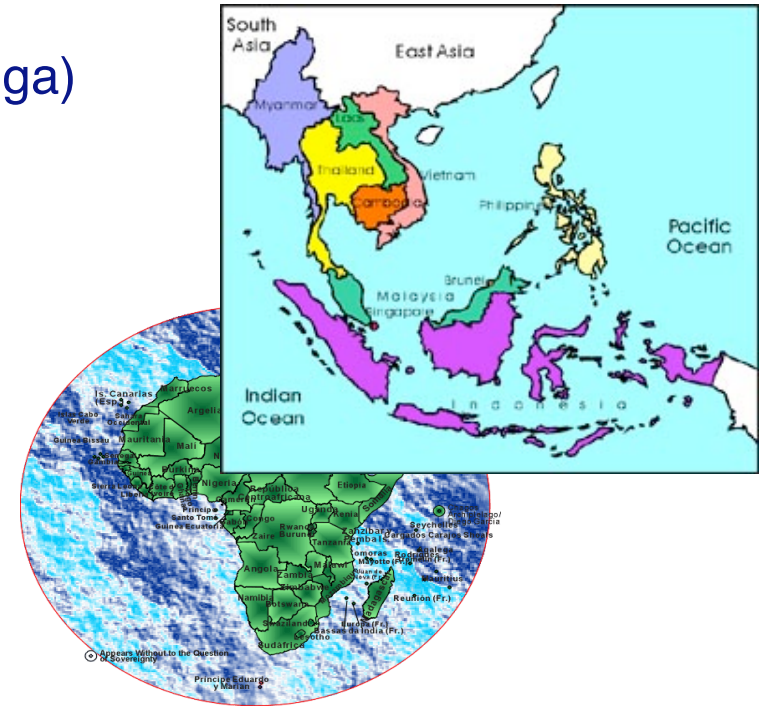
Latin American Nuclear Free Zone (LANFZ) Treaty (1967)

- 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 develop or introduce NWs
- The four countries outside of region (US, UK, Neth, Fr) agree in a 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)



iClicker Answer

Which of the following launch locations is not part of President Obama's European-based missile defense program?

(A) Poland

(B) Romania

(C) United Kingdom

(D) Sea based

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iClicker Answer

Which of the following launch locations is not part of President Obama's European-based missile defense program?

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iClicker Question

How many sea based SM-3 intercepters will be deployed as part of President Obama's European-based missile defense program by 2018?

(A) 200

(B) 300

(D) 400

(E) more than 500

Blank

iClicker Question

How many sea based SM-3 intercepters will be deployed as part of President Obama's European-based missile defense program by 2018?

(A) 200

(B) 300

(D) 400

(E) more than 500

Horizontal Nuclear Non-Proliferation

1955: Atoms for Peace (see http://**www.iaea.org**/About/history_speech.html)

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)

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 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 October 2006. Accession of Kim Jong-Il in 2011 has lead to present crisis with significant uncertainty with regards to North Korea's intentions.
- Iran has been a complex case; currently concerns that Iran may be close to acquiring nuclear weapons are rising quickly.

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

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: 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
- Model 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 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

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

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)

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

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)

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

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

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
- 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)

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

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?

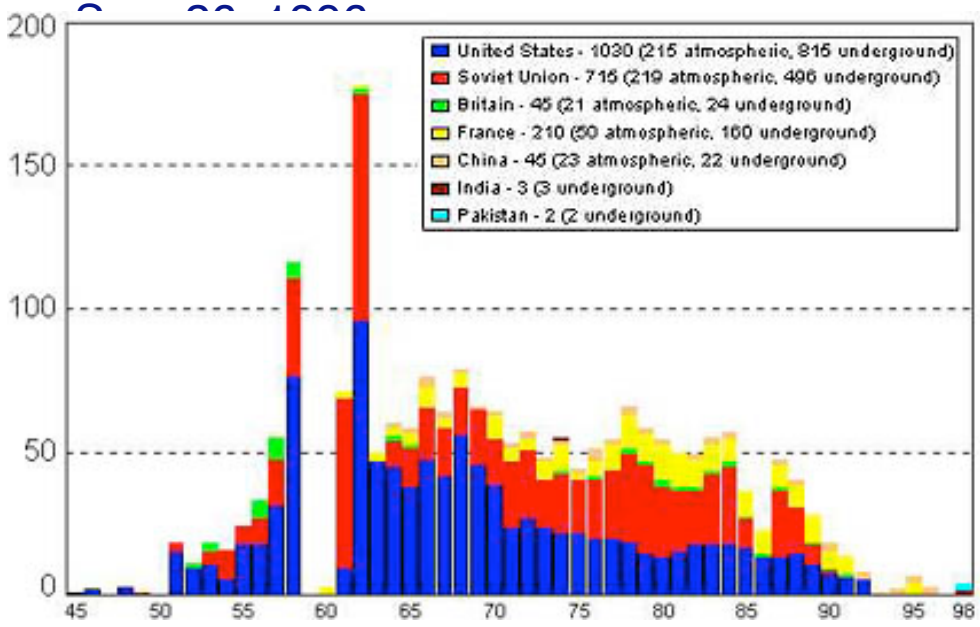
CTBTO PREPARATORY COMMISSION | preparatory commission for the comprehensive nuclear-test-ban treaty organization

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		



Nuclear Arms Control Eras

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

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!

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

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

➔First steps (1) New START

(2) Nuclear Security Summit

New START

- Replaces SORT to expire December 2012

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 2012

- 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 to deployed strategic warheads 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

Physics 280: Session 27

Questions

News and discussion

Module 8: Nuclear Arms Control cont'd

➔ Nuclear Proliferation and the NPT

Physics 280: Session 27

ICES forms are available online

To use ICES Online, click the following URL:

https://ices.cte.uiuc.edu/

Your participation will help us to further improve the course and to obtain the support needed to continue the course!

Please participate !! (so far 9 of 58 …)

News and Discussion

Ratcheting up rhetoric, North Korea's mi threatens t South's lea ashes

By Associated Pres April 23

The Washington Post

For days, North Korea has railed against South Korean President Lee Myung-bak and conservative South Korean media for criticizing its rocket launch and the celebrations of the centennial of Kim Il Sung's birth. But the military message, attributed to the "special operation action group" of the Korean People's Army's Supreme Command, was unusual in its specificity.

"Once the above-said special actions kick off, they will reduce all the rat-like groups and the bases for provocations to ashes in three or four minutes, in much shorter time, by unprecedented peculiar means and methods of our own style," it said.

The threat comes as North Korea's new commander in chief, Kim Jong Un, makes a show of support for the "military first" policy championed by his late father and predecessor, Kim Jong Il. North Korea marks the 80th anniversary of the founding of its army Wednesday.

In November 2010, after issuing a warning to the South Korean government, North Korean troops showered artillery on a front-line island in disputed western waters held by South Korea. The attack killed four people, including two civilians.

News and Discussion

Reuters

Exclusive: North Korea's nuclear test ready "soon"

8:38am EDT

By Benjamin Kang Lim

BEIJING (Reuters) - North Korea has almost completed preparations for a third nuclear test, a senior source with close ties to Pyongyang and Beijing told Reuters, which will draw further international condemnation following a failed rocket launch if it goes ahead.

Now the North appears to be about to carry out a third nuclear test after two in 2006 and 2009.

"Soon. Preparations are almost complete," the source said when asked whether North Korea was planning to conduct a nuclear test.

This is the first time a senior official has confirmed the planned test and the source has correctly predicted events in the past, telling Reuters about the 2006 test days before it happened.

The rocket launch and nuclear test come as Kim Jong-un, the third of his line to rule North Korea, seeks to cement his grip on power.

Kim took office in December and has lauded the country's military might, reaffirming his father's "military first" policies that have stunted economic development and appearing to dash slim hopes of an opening to the outside world.

Washington, Seoul and Tokyo, which have most to fear from any North Korean nuclear threat, are watching events anxiously and many observers say that Pyongyang may have the capacity to conduct a test using highly enriched uranium for the first time.

Defense experts say that by successfully enriching uranium, to make bombs of the type dropped on Hiroshima nearly 70 years ago, the North would be able to significantly build up stocks of weapons-grade nuclear material.

The Dangers of Nuclear Proliferation

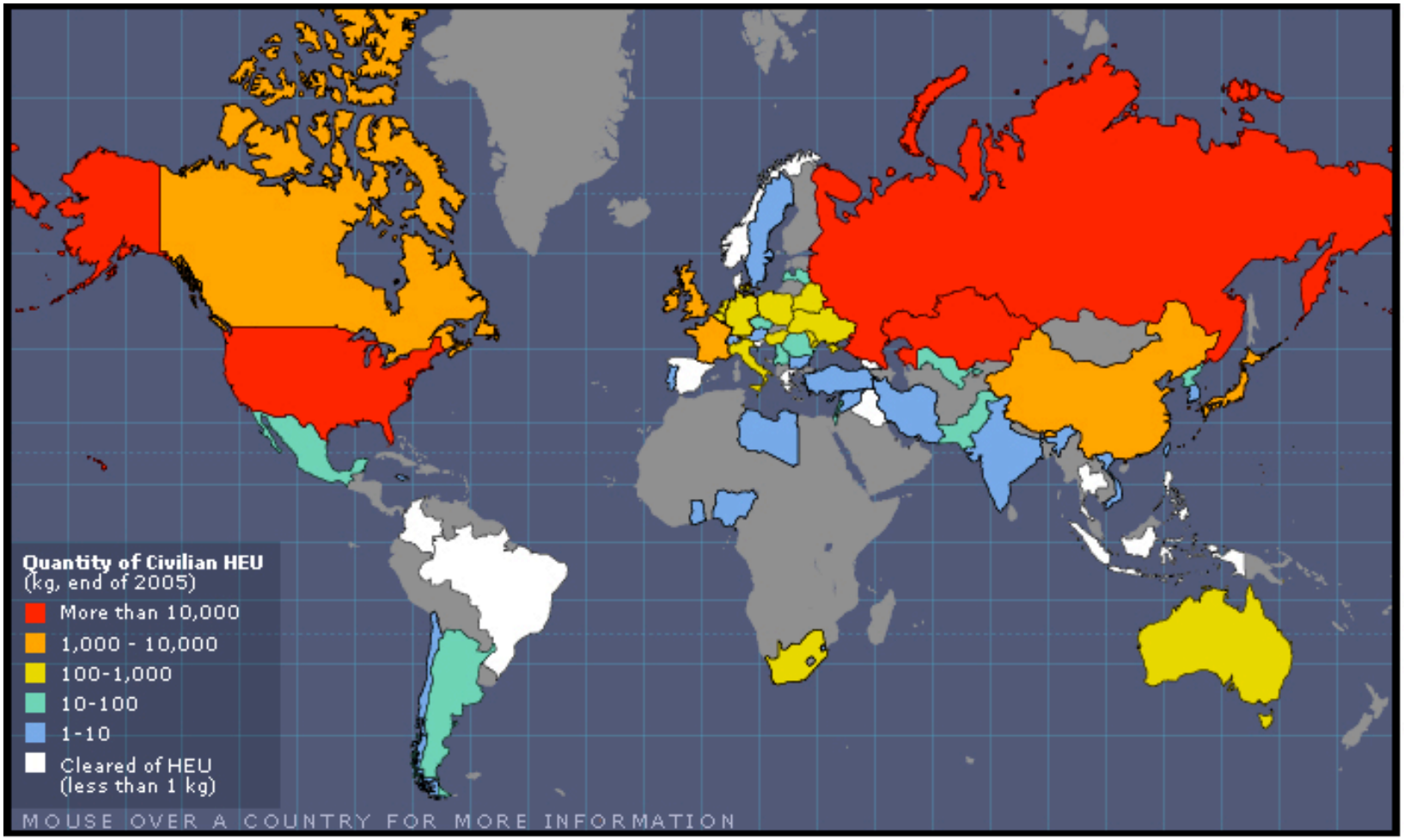
- Governments unfriendly to the U.S. are increasingly trading with one another to obtain nuclear weapons
- Nuclear weapon materials and technology are increasingly being proliferated by private networks, like the A.Q. Khan network based in Pakistan
- Theft, diversion, and sale of nuclear materials and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

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"



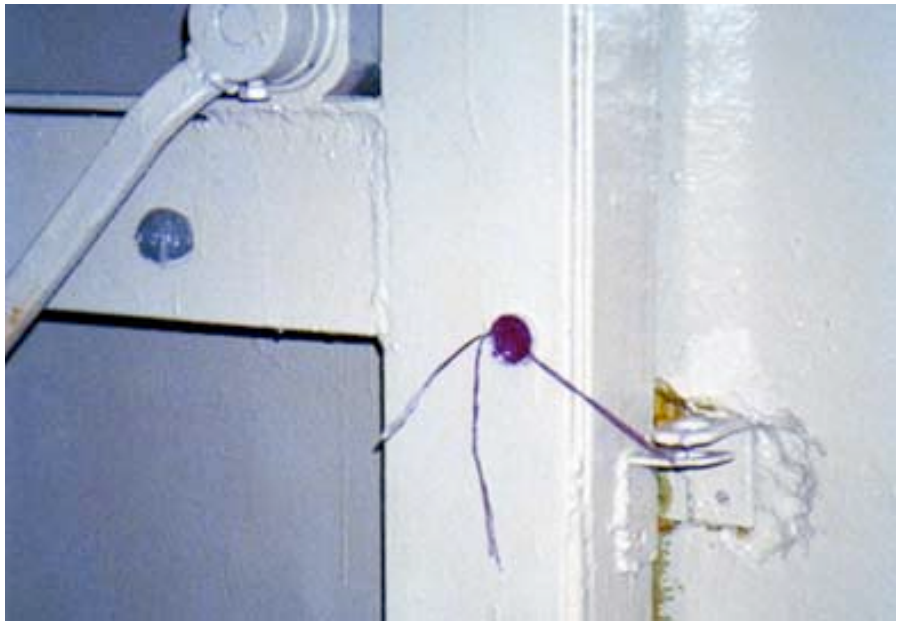
Availability of Nuclear Weapon Materials in the Former Soviet Union

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

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

Delivery Methods Other Than Long-Range Ballistic Missiles Result in Significant Threat to US National

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*

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 depart secretly from 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.

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

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 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

BEFORE: 20 SEP 02

AFTER: 20 JUN 04

iClicker Question

The Non Proliferation Treaty (NPT) was signed in what year?

(A) 1961

(B) 1966

(C) 1968

(D) 1970

(E) 1975

Blank

iClicker Question

The Non Proliferation Treaty (NPT) was signed in what year?

(A) 1961

(B) 1966

(C) **1968**

(D) 1970

(E) 1975

iClicker Question

The Non Proliferation Treaty (NPT) went into force what year?

(A) 1968

(B) 1970

(C) 1975

(D) 1982

(E) 1995

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iClicker Question

The Non Proliferation Treaty (NPT) went into force what year?

(A) 1968

(B) **1970**

(C) 1975

(D) 1982

(E) 1995

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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iClicker Answer

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

(A) 1981

(B) 1987

(C) 1991

(D) 1993

(E) 1996

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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iClicker Answer

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

(A) 1981

(B) 1987

(C) 1991

(D) 1993

(E) 1996

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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iClicker Answer

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

(A) 1981

(B) 1987

(C) 1991

(D) 1993

(E) 1996

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

Nuclear Safeguards

(slides prepared by Physics 280 TA Matthew Duchene)

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)

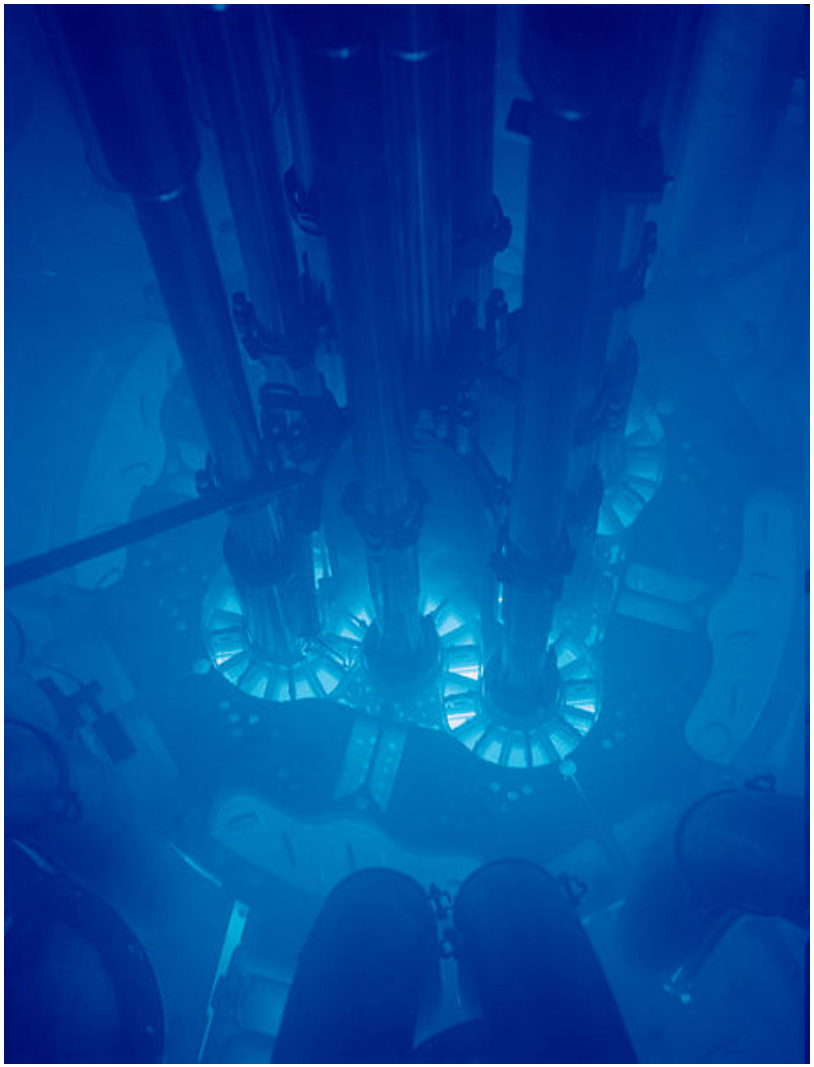
NDA tools can consist of any measurement device that does not destroy the sample.

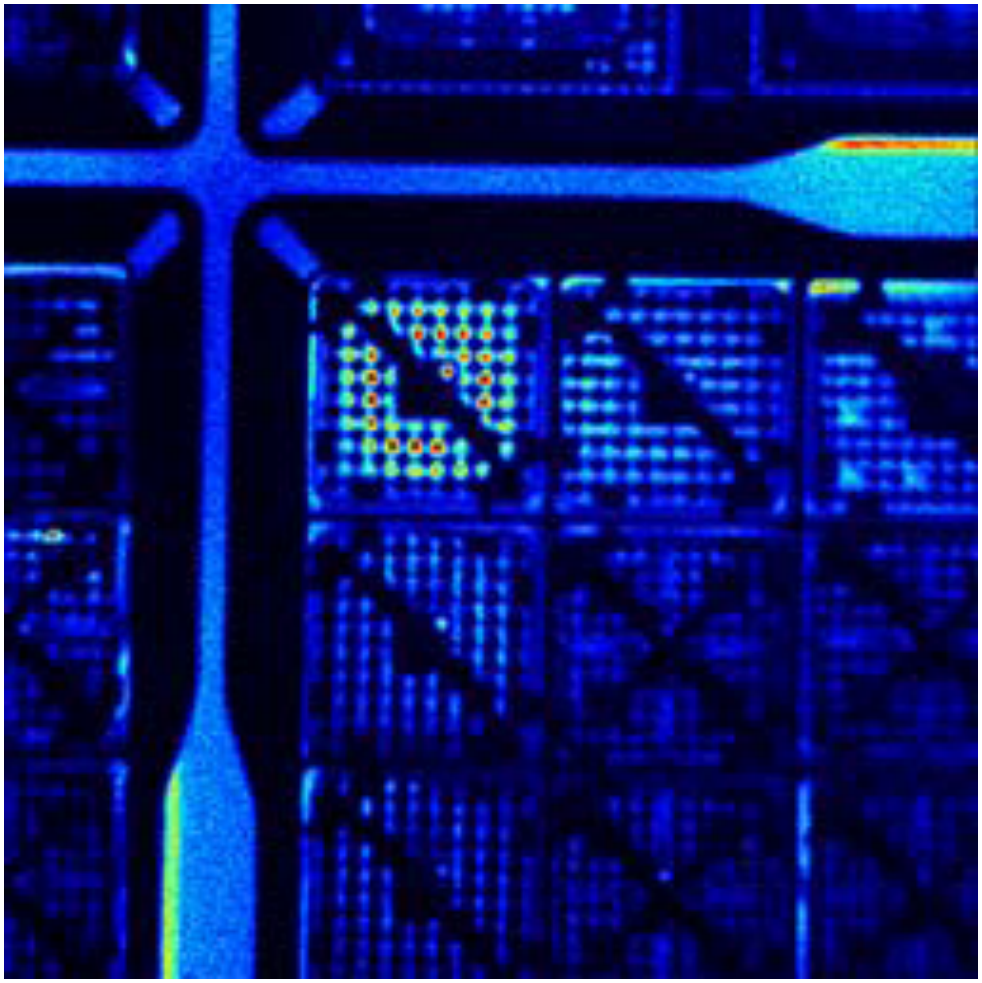
- Mass scales
- Radiation detectors/neutron counters
- Cherenkov radiation viewing devices

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
- Titration
- 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.

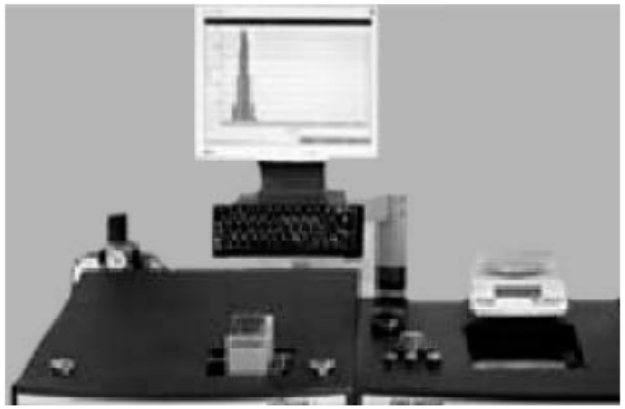


Figure 11: Basic Methodology 2
Samples are brought to a field laboratory for analysis.

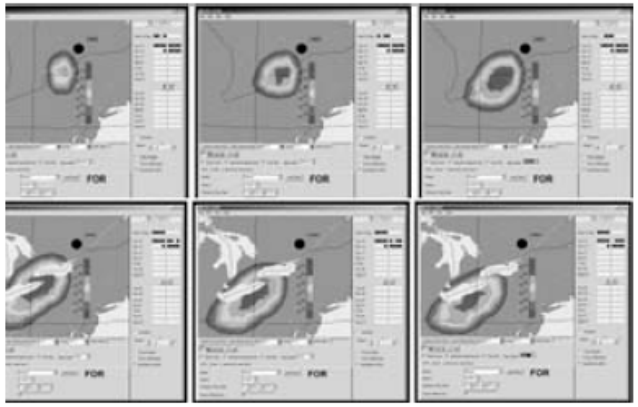


Figure 12: Basic Methodology 3
The sample analysis data is combined with meteorological data and suitable atmospheric modelling to provide an estimate of the source direction.

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

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

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

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.

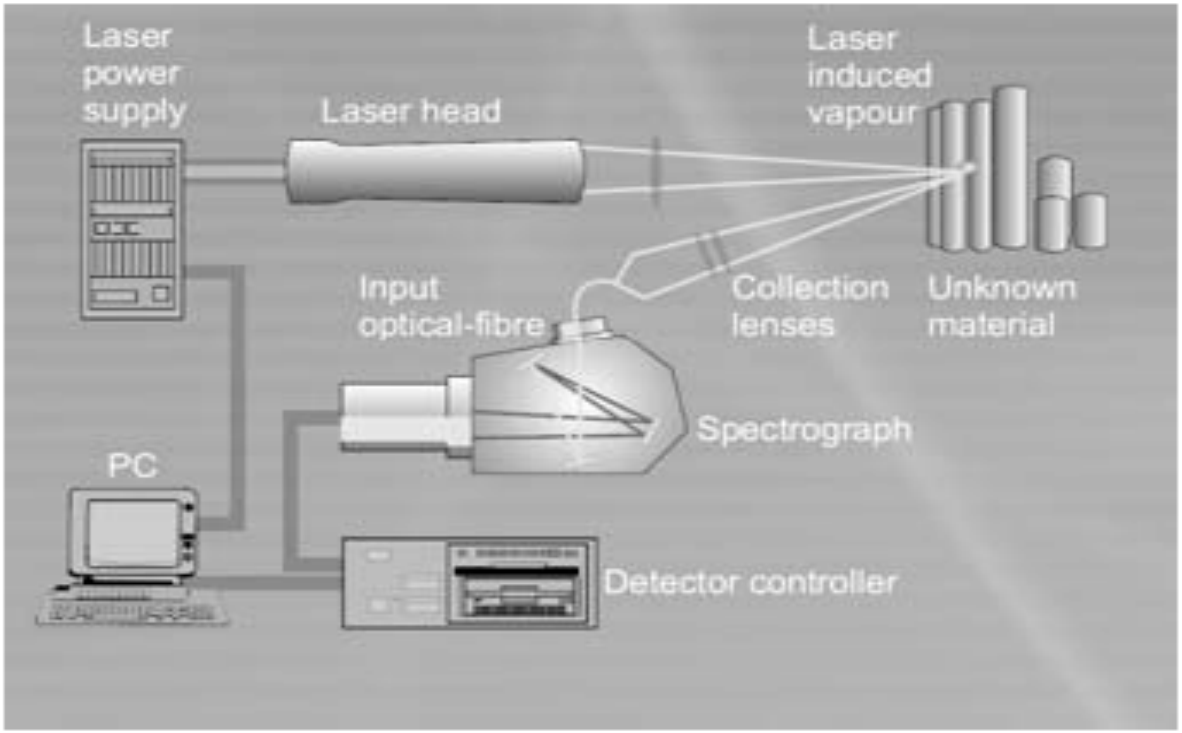


Figure 6: Basic Methodology 2
LIBS is comprised of (i) a laser system to ablate the surface of the material to be analyzed to create a micro-vapour, and (ii) a spectrometer to generate a spectroscopic profile of the micro-vapour's constituent components.

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

Material Unaccounted for, Measurement Errors

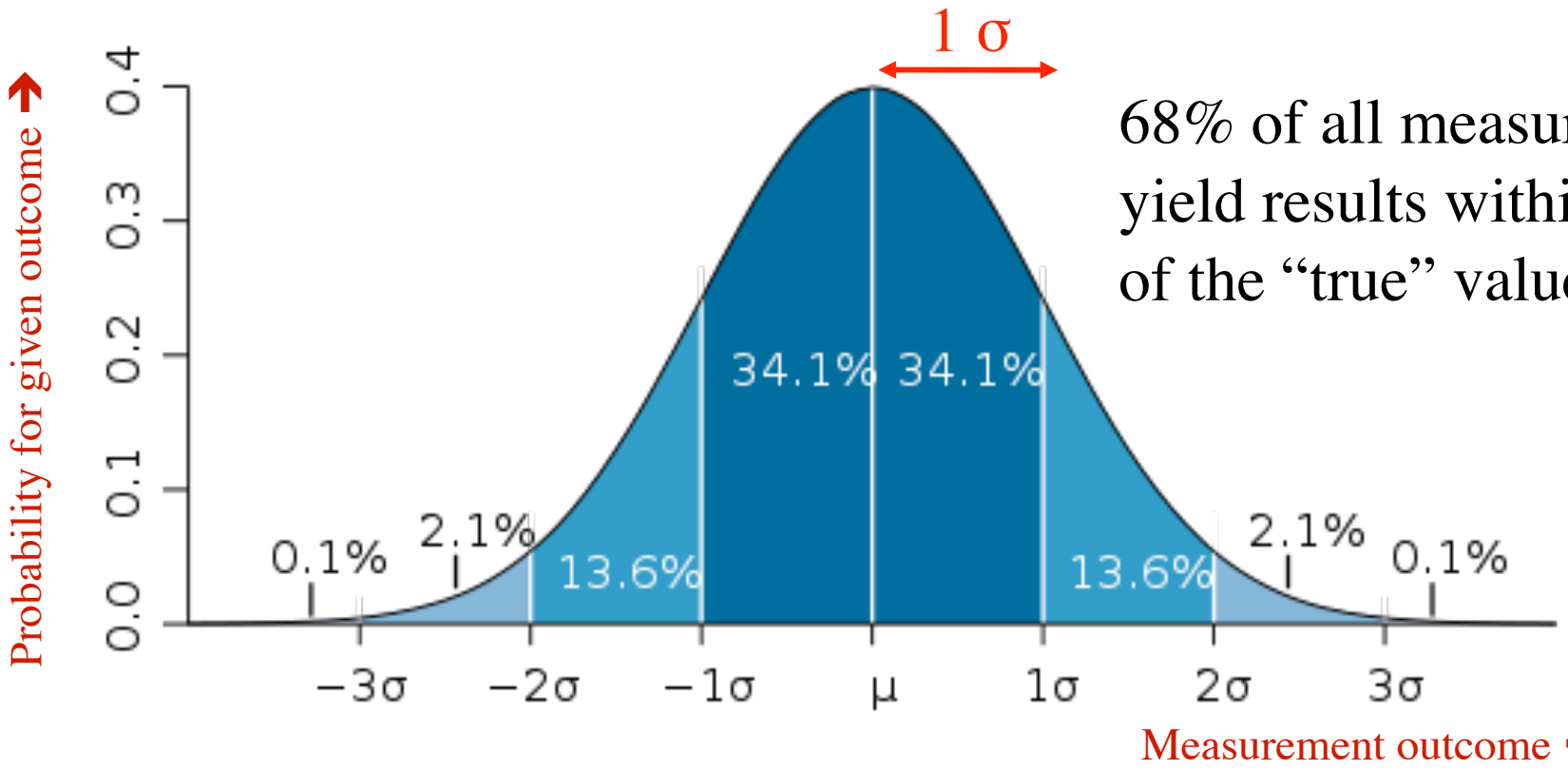
Material Unaccounted For (MUF): The accounting difference between the amount of recorded material transferred in and out of a facility and recorded inventory at the beginning and end of a particular reporting period.

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 !!

Distribution and Probabilities of Measurement Results



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

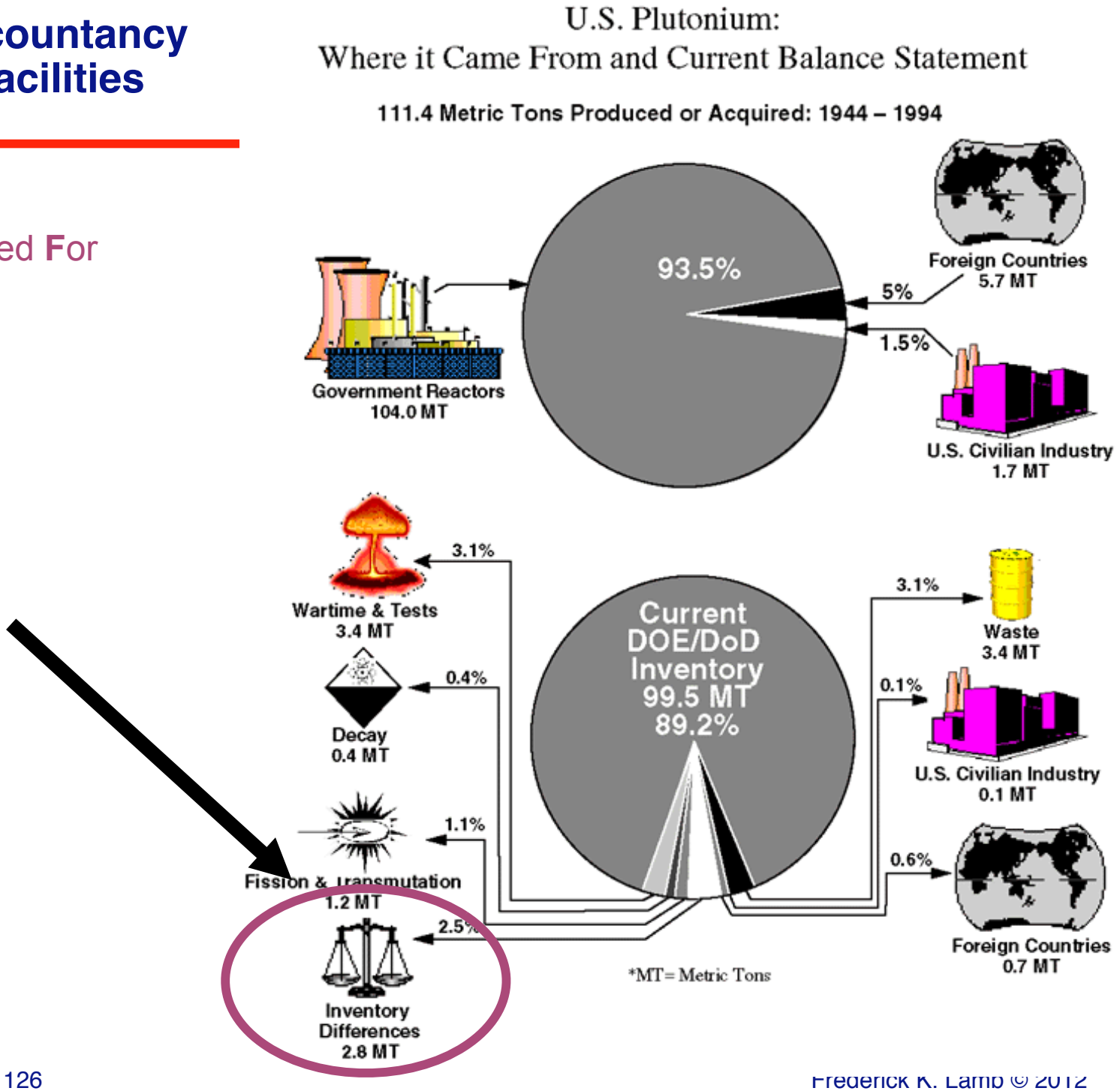
Ref: "Standard Deviation"

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.



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.

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

Physics 280: Session 28

Announcements

Final exam review:
6:30 PM, Thursday, May 3, in 144 Loomis

Final exam:
1:30 PM, Friday, May 4, in 124 Burrill Hall

Plan for This Session

Student questions

Module 8: Nuclear Arms Control (cont'd)

Movie: "Countdown to Zero" (part one)

Discussion of "Countdown to Zero"

Nuclear 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**	—

The Comprehensive Nuclear Test Ban Treaty

Main conclusions of the U.S. National Academy of Sciences Report released March 30, 2012:

- The United States no longer needs—and would not benefit from—nuclear explosive testing.
- Renewed nuclear testing would reduce U.S. security.
- U.S. ratification and entry into force of the CTBT would significantly improve our ability to detect and deter testing by other countries.

The Comprehensive Nuclear Test Ban Treaty

Specifically:

- The stockpile stewardship program has been more successful than anticipated in 1999, when the Senate last considered the CTBT.
- U.S. national monitoring and the International Monitoring System have improved to levels better than predicted in 1999.
- Advances have been made in all of the key verification technologies deployed worldwide to detect and deter nuclear test explosions:
  - Seismic
  - Hydroacoustic
  - Infrasound
  - Radionuclide
  - Satellite monitoring

Air Sampling

Air sampling can provide:

- The volume and energy of neutrons emitted by the explosion
- The explosive yield of the device
- The design of the nuclear weapon
- The age of the plutonium used (if plutonium was used)
- When the detonation took place
- The general location of the detonation
- Whether detonation was atmospheric or submerged
- The source of the nuclear materials used

Air Sampling (Cont'd)

For air sampling to be successful:

- There must be an accessible radioactive plume.
- The meteorology must be favorable.
- The background radionuclide concentration must be low relative to the concentration of the nuclides in the plume.

The failure to find radioactive effluents in could be due to two reasons:

- The test was buried deeper than the 2006 event.
- A broad region of high atmospheric pressure suppressed the exhalation of the xenon isotopes when they might have been detected (before they decayed to background levels.

The Comprehensive Nuclear Test Ban Treaty

In summary:

- More is known today than ever before about the U.S. nuclear arsenal and there is no technical or military reason to resume testing.
- National and international test ban monitoring and verification capabilities have improved immensely.
- The security value of the CTBT for the U.S. is greater than ever.

North Korea's 2006 Nuclear Test — A Case Study

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

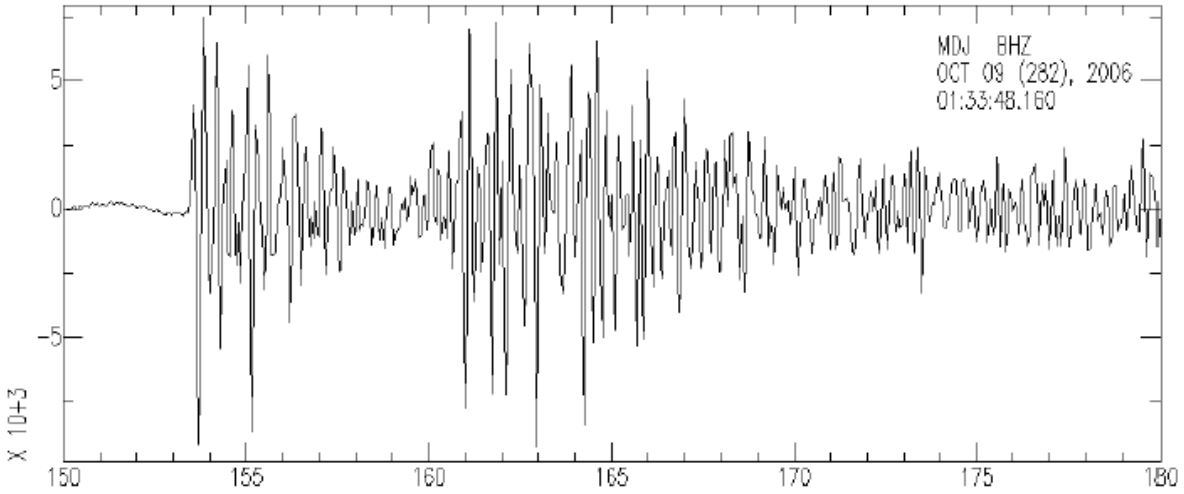
One week later, the Office of the Director of National Intelligence confirmed detection of radioactive debris and stated that North Korea had conducted a nuclear explosion with a yield of less than 1 kiloton

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

Detection of North Korea's Nuclear Test



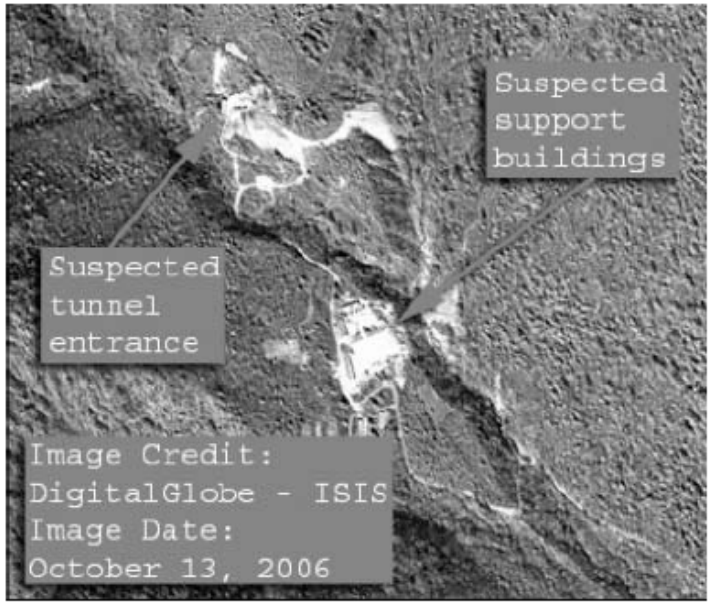


Figure 3: Satellite imagery of the suspected test site (location 41.28 N 129.08 E)[14]

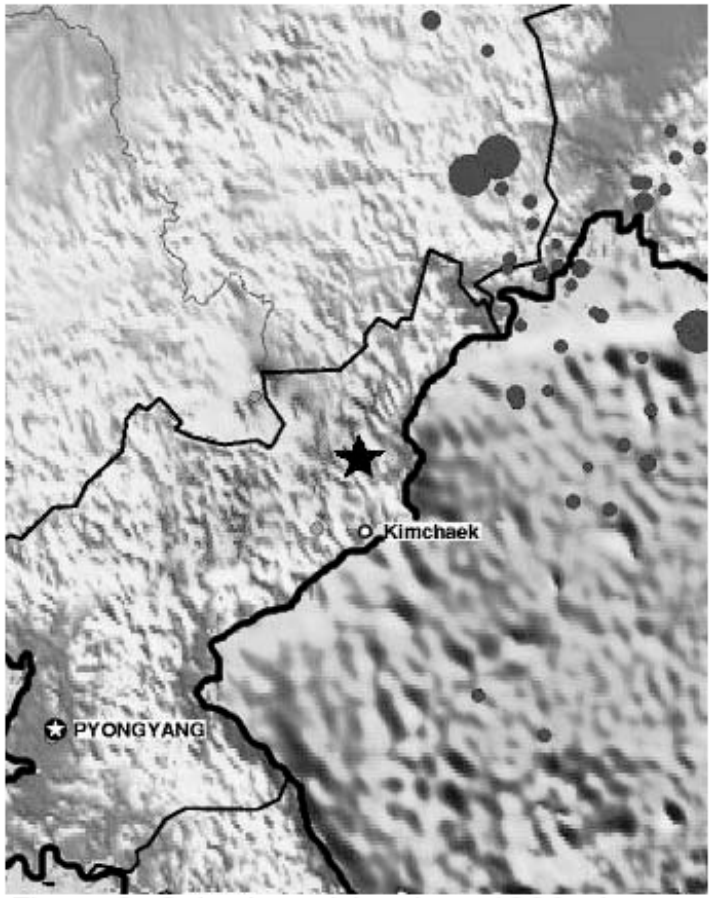


Figure 2: Seismic activity since 1990; the star shows the location of the North Korean nuclear test explosion
Source: United States Geological Survey (USGS) – National Earthquake Information Center (NEIC)

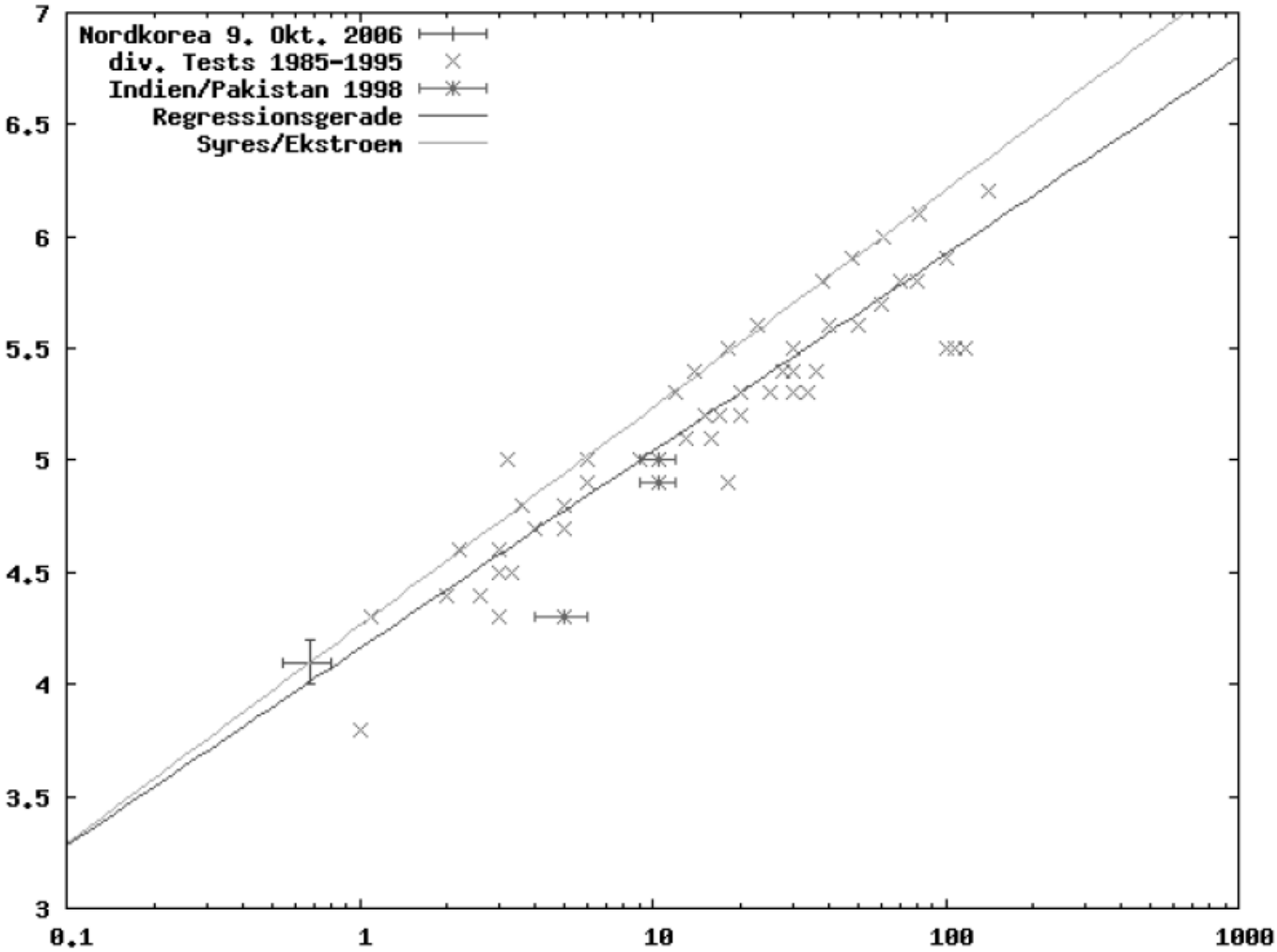
Source: Martin B. Kalinowski, Ole Ross, Analysis and Interpretation of the North Korean Nuclear Test, INESAP Information Bulletin No. 27, Dec. 2006

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

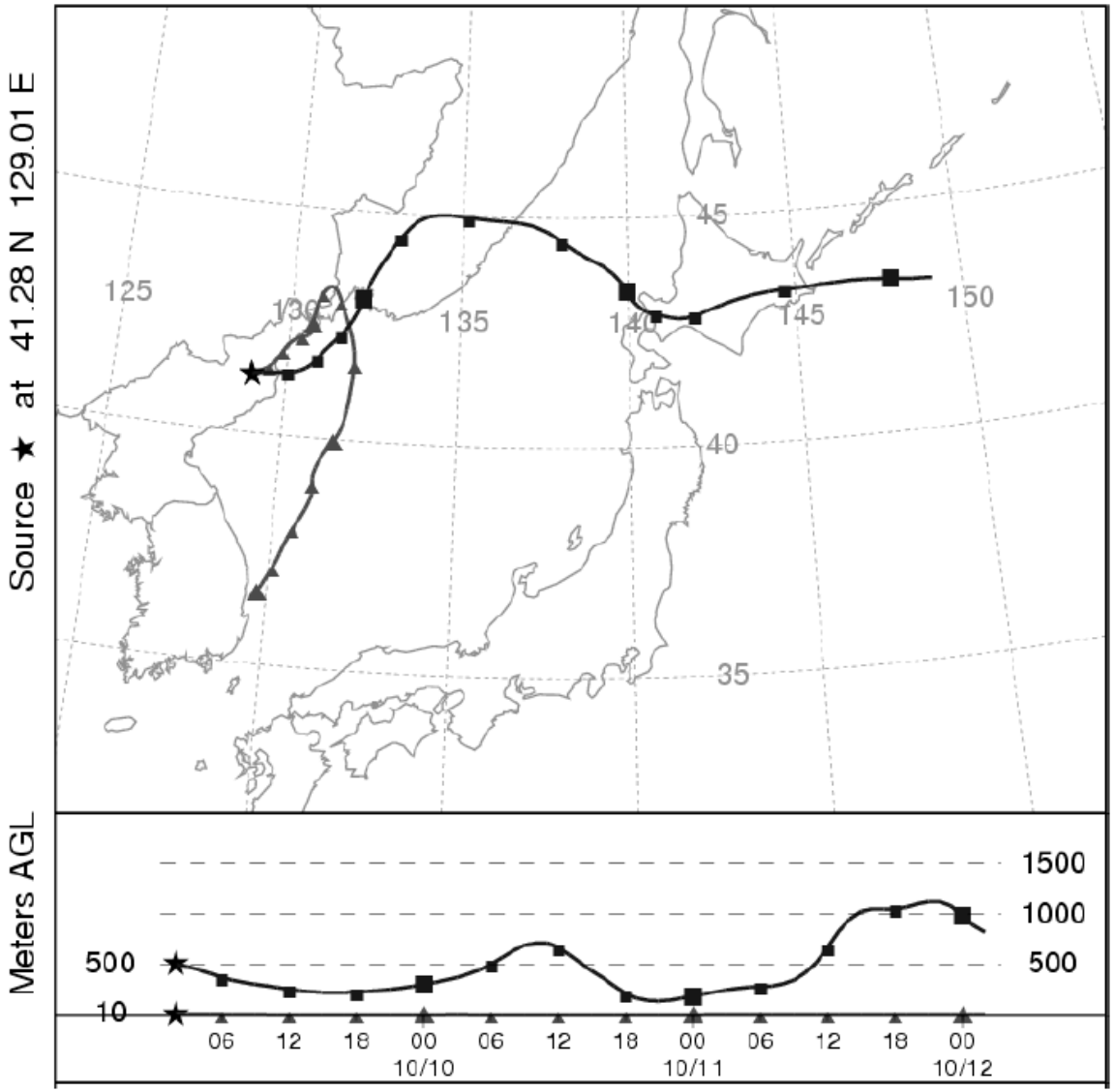
Source: Martin B. Kalinowski, Ole Ross, Analysis and Interpretation of the North Korean Nuclear Test, INESAP Information Bulletin No. 27, Dec. 2006

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



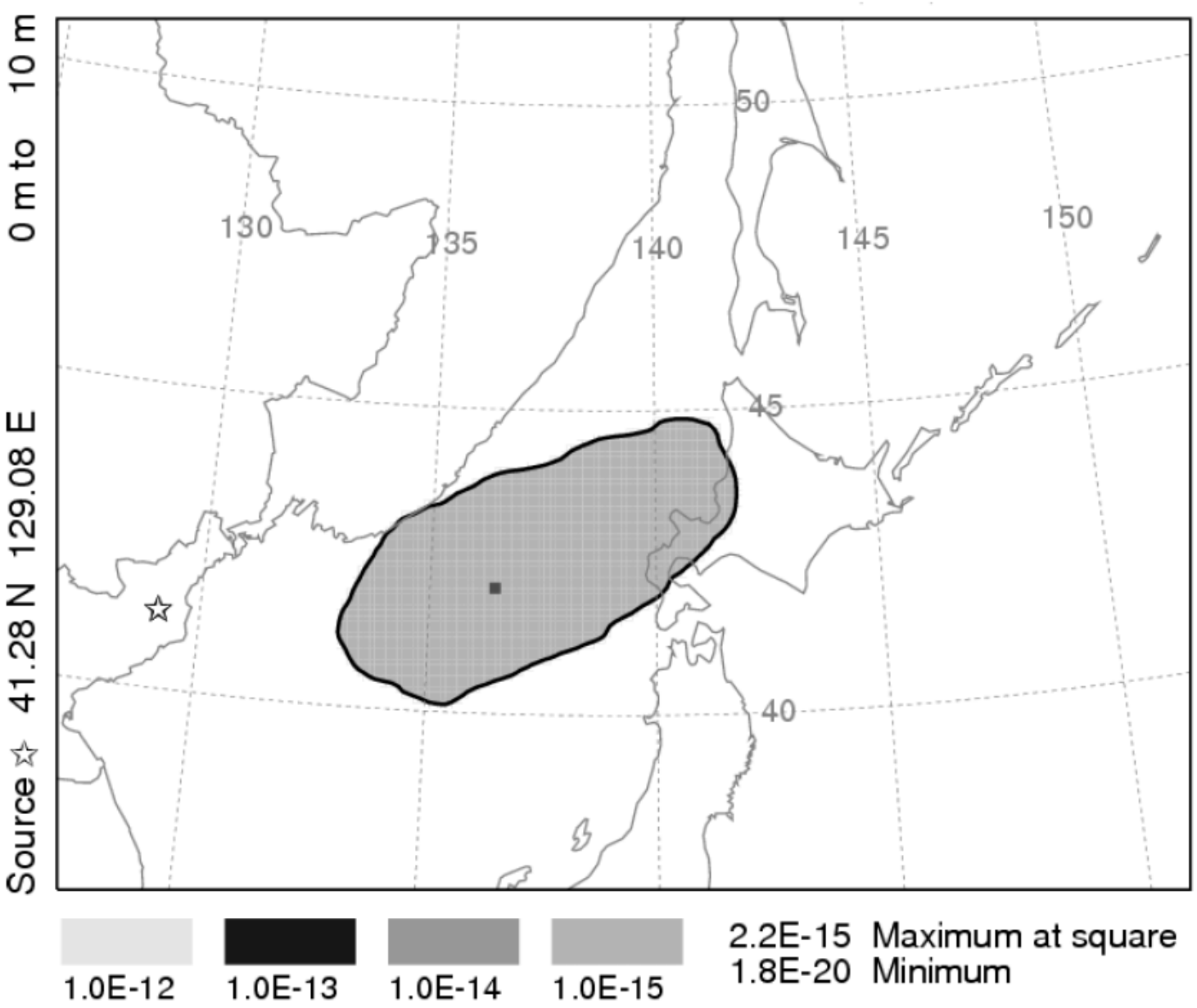
Source: Martin B. Kalinowski, Ole Ross, Analysis and Interpretation of the North Korean Nuclear Test, INESAP Information Bulletin No. 27, Dec. 2006

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

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

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.

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

North Korea's 2009 Nuclear Test

On May 25, 2009, North Korea gave China and the United States less than one hour's notice that it would conduct a nuclear test.

The explosion took place at 00:54 UTC:

A 02:24 UTC the CTBTO issued its first report on the time, location and magnitude of the event.

A few hours later, North Korea publicly announced "one more successful underground nuclear test...on a new higher level in terms of explosive power and technology".

Based on seismic data, the estimated yield was a few kilotons, about 5 times larger than the 2006 test.

No radionuclides from the test were unambiguously detected.

There is a consensus among scientists and CTBTO officials that the 25 May 2009 event was most probably a nuclear test. Explain why.

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

Blank

iClicker Answer

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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

Blank

iClicker Answer

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A. 2010

B. 2011

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D. 2015

E. 2018

Module 8: Nuclear Arms Control

Video: “Countdown to Zero”

Physics 280: Session 29

Announcements

Final exam review:
6:30 PM, Thursday, May 3, in 144 Loomis

Final exam:
1:30 PM, Friday, May 4, in 124 Burrill Hall

Plan for This Session

Student questions

News and discussion

Movie: “Countdown to Zero” (part one)

Discussion of “Countdown to Zero”

News and Discussion

Signs of an Asian Arms Buildup in India's Missile Test

By HEATHER TIMMONS and JIM YARDLEY
Published: April 19, 2012

NEW DELHI — India's successful test on Thursday of a long-range ballistic missile capable of carrying a nuclear warhead is the latest escalation of an arms race in Asia, where the assertiveness and rising military power of China has rattled the region and prompted a forceful response from the Obama administration.

The New York Times April 20, 2012

Reuters

The Agni 5 missile was launched from Wheeler Island off the eastern coast of India on Thursday.

News and Discussion

The 51-foot-long Agni 5 reached an altitude of about 430 miles in the test, the Indian government said, and has a range of 3,100 miles. By United States measures, that distance technically makes it an intermediate missile, short of the 3,400-mile minimum that defines intercontinental ballistic missiles, though such quibbling means little if China is the aim.

"Agni 5 will give India complete coverage of targets in China," Poornima Subramaniam, an Asia-Pacific armed forces analyst at IHS Jane's Defense, said in an e-mail. "Agni 5 technologically narrows the missile gap between India and China, while the strategic balance between the two rivals is still tipped in China's favor."

News and Discussion

Pakistan Says It Test-Fires Nuclear-Capable Missile

By SALMAN MASOOD
Published: April 25, 2012

ISLAMABAD, Pakistan — Pakistan successfully tested an improved intermediate-range ballistic missile early on Wednesday, according to a statement by the Pakistani military.

The New York Times April 26, 2012

European Pressphoto Agency

In a photo released by Pakistan's spy service, the Hatf-4 Shaheen-1A soared from an undisclosed location in Pakistan on Wednesday.

News and Discussion

Mansoor Ahmed, a defense analyst in Islamabad, the capital, said Wednesday's launching appeared to be of an improved intermediate-range missile, with a possible range of 466 to 620 miles. The missile could be equipped with warheads designed to evade missile-defense systems, he added.

iClicker Question

Which of the following countries has not openly tested a nuclear weapon?

A. India

B. Israel

C. North Korea

D. Pakistan

E. China

Blank

iClicker Question

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C. North Korea

D. Pakistan

E. China

iClicker Question

Nuclear Weapon Proliferation

Which of the following countries is *not* a party to the Nuclear Nonproliferation Treaty?

A. India

B. Israel

C. North Korea

D. Pakistan

E. All of the above

Blank

iClicker Question

Nuclear Weapon Proliferation

Which of the following countries is *not* a party to the Nuclear Nonproliferation Treaty?

A. India

B. Israel

C. North Korea

D. Pakistan

E. All of the above

iClicker Question

Nuclear Weapon Proliferation

Which of the following countries signed the Nuclear Nonproliferation Treaty but then created a clandestine program to develop nuclear weapons?

A. Iraq

B. Libya

C. North Korea

D. Iran

E. All of the above

Blank

iClicker Question

Nuclear Weapon Proliferation

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A. Iraq

B. Libya

C. North Korea

D. Iran

E. All of the above

iClicker Question

Which two countries have started preventive wars, ostensibly to prevent an adversary from obtaining nuclear weapons?

A. India, Pakistan
B. Israel, China
C. The United States, Russia
D. The United States, Israel
E. The United States, India

Blank

iClicker Question

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A. India, Pakistan

B. Israel, China

C. The United States, Russia

D. The United States, Israel

E. The United States, India

Module 8: Nuclear Arms Control

Video: “Countdown to Zero”

Module 8: Nuclear Arms Control

Discussion of “Countdown to Zero”

What Should Be Our Goal?

Two years after he assumed office, President Reagan said

"I support a zero option for all nuclear arms. As I've said before, my dream is to see the day when nuclear weapons will be banished from the face of the Earth."

This should be our urgent goal.

Requirements for Verifying Zero Nuclear Weapons

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

2.1 "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

2.2 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.

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

Blank

iClicker Answer

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

A. 1981

B. 1987

C. 1991

D. 1993

E. 1996

iClicker Question

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

A. 1981

B. 1987

C. 1991

D. 1993

E. 1996

Blank

iClicker Answer

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

A. 1981

B. 1987

C. 1991

D. 1993

E. 1996

iClicker Question

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

A. 1981

B. 1987

C. 1991

D. 1993

E. 1996

Blank

iClicker Answer

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

A. 1981

B. 1987

C. 1991

D. 1993

E. 1996

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

Blank

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