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Title: Fundamentals of International Safeguards and Nuclear Nonproliferation

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Fundamentals of International Safeguards and Nuclear Nonproliferation

IMS Materials Summer School

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Nuclear Nonproliferation

- **What is our goal?**
  - Prevent nuclear weapon proliferation

  ↑ Vertically – decrease capabilities of existing nuclear states

  ⟶ Horizontally – decrease number of states/non-state actors attempting to possess nuclear weapons
- **What can we do?**
  - Encourage/ensure peaceful nuclear uses
  - Secure, safeguard, and/or dispose of dangerous nuclear and radiological material
  - Detect and control the proliferation of related WMD technology and expertise
- **How can we do it?**
  - Nuclear Nonproliferation Treaty:

    ⟶ Bans acquisition of nuclear weapons by non-weapon states
  - Comprehensive Test Ban Treaty:

    ⟶ Bans nuclear explosions

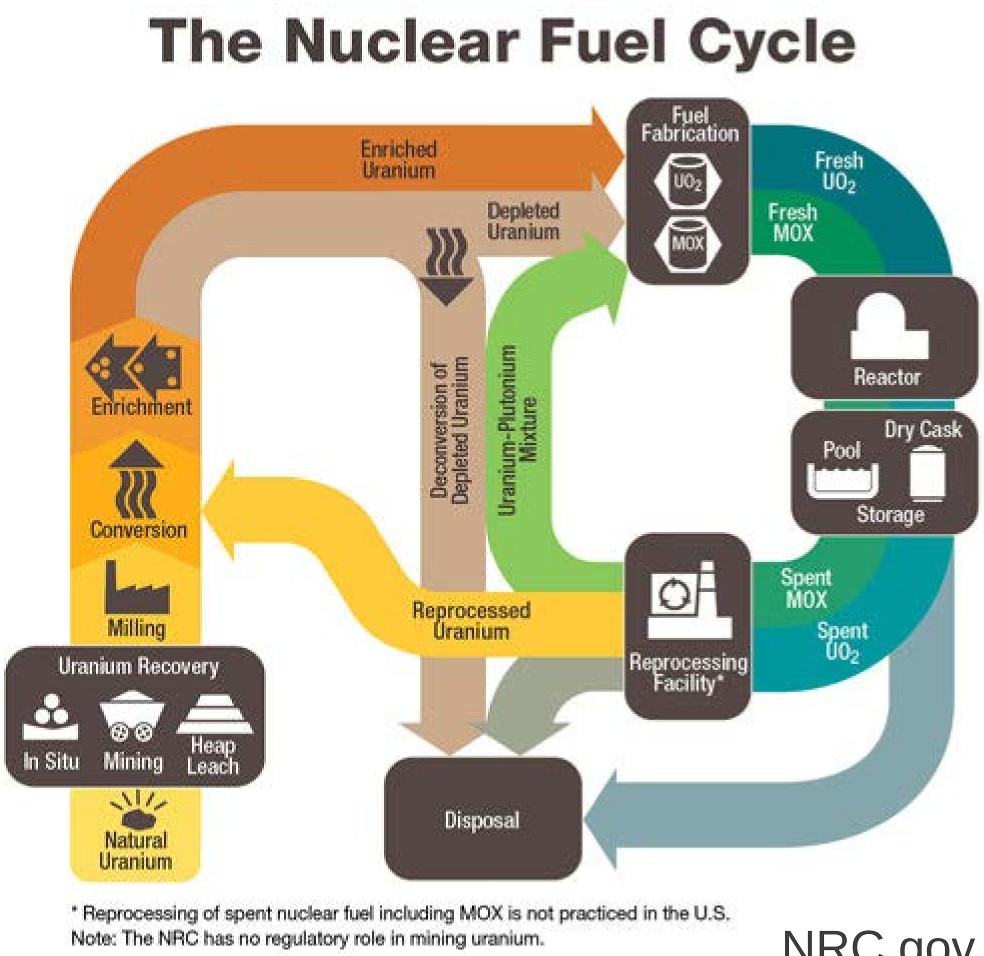
Note: Verification is the key element

Science and technology play a vital role

Nuclear Test at the Mururoa atoll, French Polynesia (courtesy *The Atlantic*)

International Safeguards

- "Delivering Effective Nuclear Verification for World Peace"
- 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
- Inspect nuclear facilities worldwide, monitor amounts of nuclear materials to ensure that it isn't going to illicit uses



NRC.gov

International Safeguards: History

- **During World War II, efforts began to develop a nuclear weapon for fear that Germany was already doing so**
- **LANL was selected as the central facility for U bomb research and design**
- **The first test took place at 5:30am on July 16, 1945 at the Trinity Test Site**
- **The final decision to drop the bomb was made on July 25**
  - "Little Boy" an HEU Gun type assembly was dropped on Hiroshima August 6, 1945
  - "Fat Man" – a weapons grade Pu implosion assembly was dropped on Nagasaki August 9, 1945
  - Japan surrendered on August 10, 1945

- **An arms race emerged as the first Soviet reactor went critical on December 25, 1946**
- **500 tests between 1945-1967**
- **70,000 warheads of 65 variations were built from 1945-1990**

The Formation of the IAEA

- **Eisenhower delivered his "Atoms for Peace" speech to the UN General Assembly on December 8, 1953**
  - Warned of the dangers of global proliferation and called for the establishment of an international atomic energy agency to control nuclear stockpiles
- **The IAEA Statute came into force on July 29, 1957 with the goal to facilitate peaceful uses of nuclear energy**
  - 56 States signed the treaty in 1957, including 4 of the 5 weapon States (US, UK, USSR, France)
  - China joined in 1984
- **The first safeguards system (INFCIRC/26) was established on March 30, 1961**
- **In August 1965, the first treaty to prevent the spread of nuclear weapons was drafted**

Source(s):
http://fas.org/nuke/control/npt/

The Nonproliferation Treaty (NPT)

- **The NPT has Three Pillars:**
  - ❑ Stop the further spread of nuclear weapons
  - ❑ Provide a sound basis for international cooperation in peaceful uses of nuclear energy
  - ❑ Commit all parties to undertake negotiations in good faith on disarmament
- **Intended to provide stability and country behavior predictability**
- **62 States signed the Nuclear Non-Proliferation Treaty (NPT) on July 1, 1968**
- **Review Conferences are held every 5 years since to ensure that the provisions of the treaty are being properly realized**
- **The DPRK is the only nation to have exercised the right to withdraw provided in Article X**

Source(s):
http://fas.org/nuke/control/npt/

The IAEA Today

Currently, the IAEA is working to achieve….

- **Universal acceptance of the AP**
- **Integrated safeguards**
  - Non-discriminatory and tailored to specific facility types
- **Safeguards-by-design**
  - Integrated within a facility's design, covering safeguards and security
- **Unattended monitoring & data integration**
  - Robust data management systems to reduce on-site inspector presence
- **State-level concept/approach**
  - Assessing each State as a whole

Source(s):
http://www.iaea.org/safeguards/statements-repository/overview.html
http://www.iaea.org/safeguards/documents/LongTerm_Strategic_Plan_%2820122023%29-Summary.pdf

AT THE END OF 2015:

200,110	Significant quantities* of nuclear material were under IAEA safeguards
1,286	Nuclear facilities and locations outside facilities were under IAEA safeguards
2,118	In-field inspections conducted
623	Design information verifications were conducted
64	Complementary accesses were conducted

182 States	IAEA Safeguard Agreements
128 States	Additional Protocols in force

IAEA (2016). IAEA Safeguards 2016: Serving Nuclear Non-Proliferation.

* One significant quantity is the approximate amount of nuclear material for which the possibility of manufacturing a nuclear explosive device cannot be excluded.

Safeguards at LANL

Safeguards at LANL

50th Anniversary of Safeguards at LANL Celebrations

50th Anniversary Symposium:
Nuclear Safeguards at Los Alamos

Nuclear Lunches

Dr. G. Robert Keepin
Nonproliferation Summer School
at Los Alamos National Laboratory

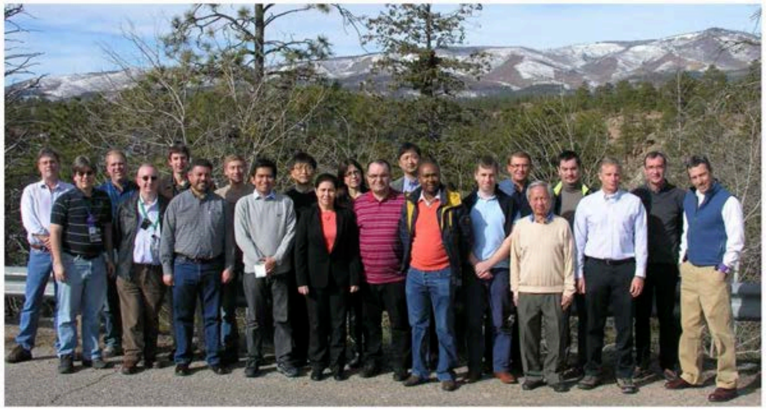
Lessons from the First 50 Years of LANL Support to International Safeguards for the Next Half Century

Tero Varjoranta
Deputy Director General, Head of Safeguards
International Atomic Energy Agency

IAEA Inspector Training

- Taking place right this minute!
- Every inspector has come through LANL for training since 1980
- We teach fundamentals of nondestructive assay
- Los Alamos has created much of the NDA technology used during inspections

60th Nondestructive Assay Inspector Training Course
Los Alamos, New Mexico
February 16-26, 2016



58th Nondestructive Assay Inspector Training Course
Los Alamos, New Mexico
February 17-27, 2015

320 Courses conducted since 1973
800 inspectors trained
5600 individuals trained in all NDA courses

Safeguards Research

- Unattended and remote monitoring systems and information management analysis.
- Detectors and electronics development for portable measurements (miniature electronics modules, CdZnTe gamma ray detectors, and fast decay-time neutron detectors).
- Technology development for holdup, confirmatory measurements, and inventory verification (generalized geometry holdup technique).
- **Experimental and computational physics and simulation for nondestructive assay technology (design of gamma ray assay systems and neutron multiplicity counters).**

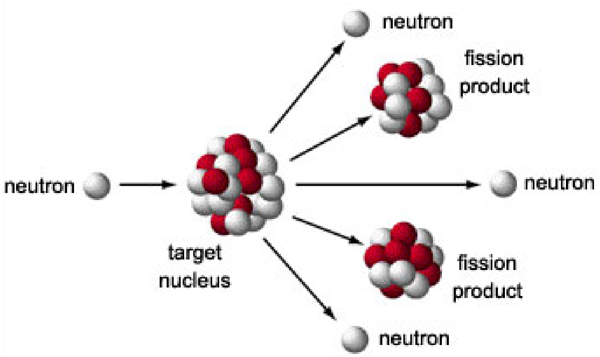
Safeguards Science and Technology

What is this?

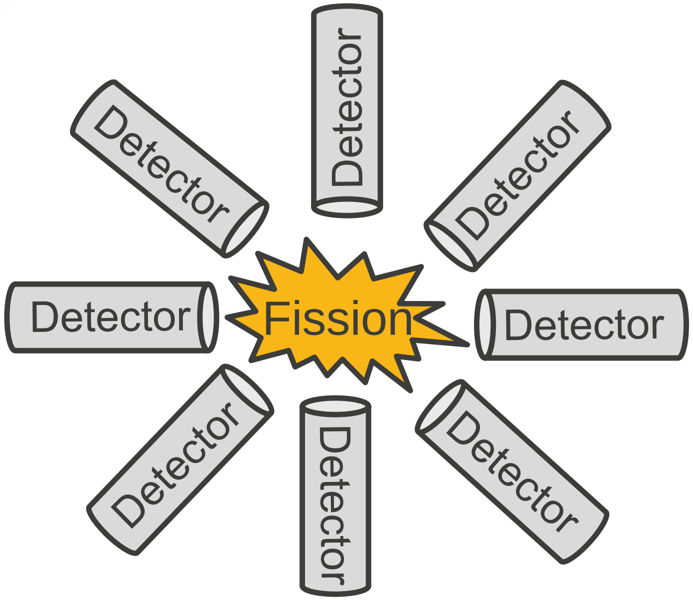
Special Nuclear Materials (SNM)

Weapons Grade Pu clad in Stainless Steel and surrounded by a Tungsten Reflector

- **SNM: Nuclear materials that can be used to make a weapon**
  - Highly Enriched Uranium (HEU)
  - Weapons Grade Plutonium (Pu)
- **We need to verify that SNM is where it should be, and in the proper amount**
  - We need specialized equipment to do this

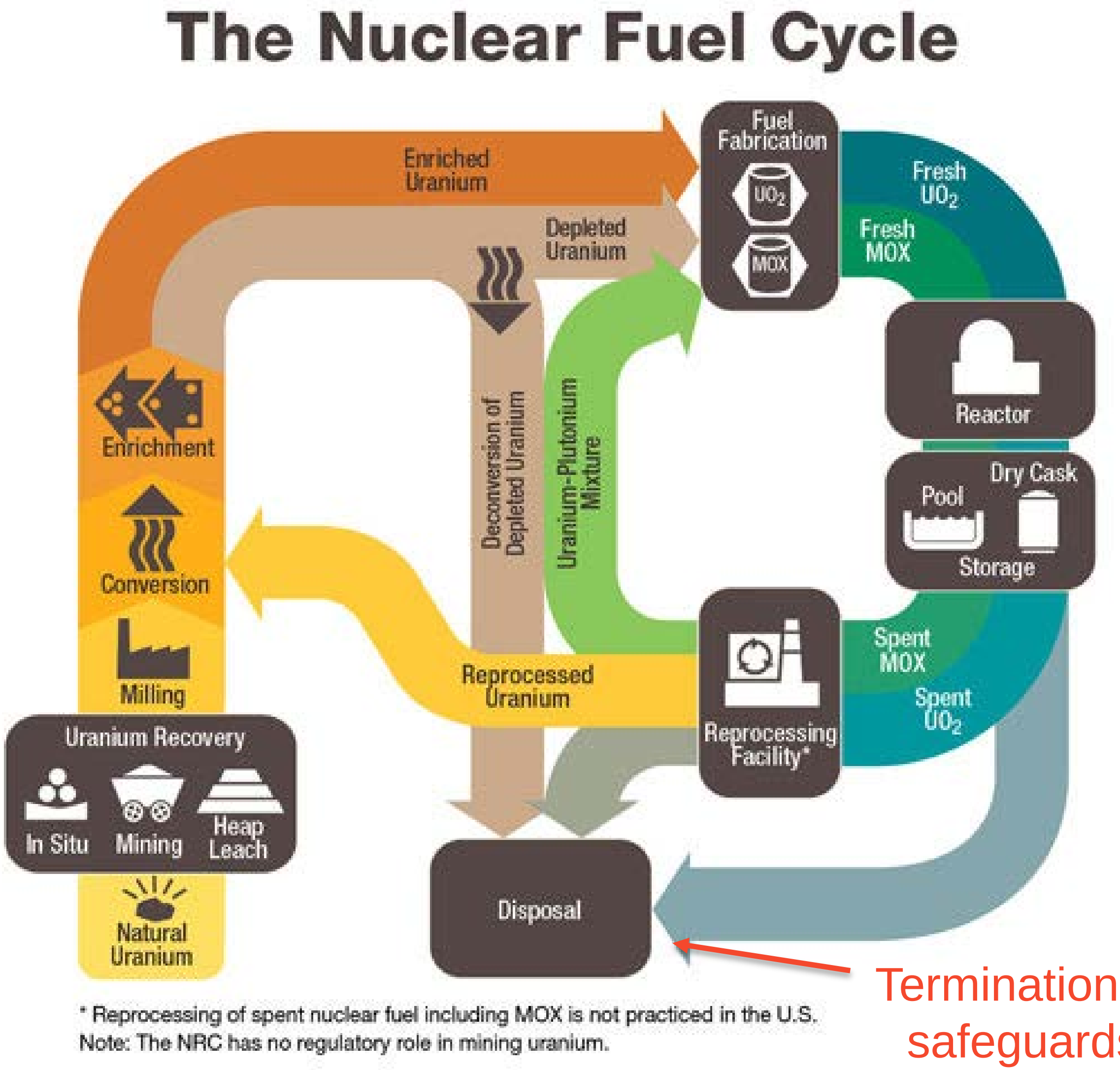


Induced Fission



Looking for neutrons detected close together in time, or gamma-rays with specific energies

Where do we find SNM?

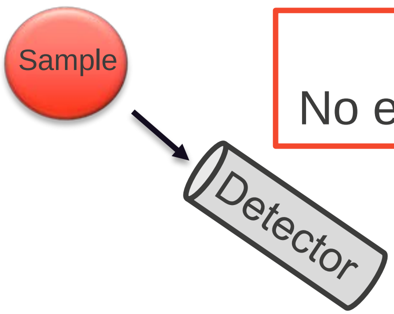


Origination of safeguards

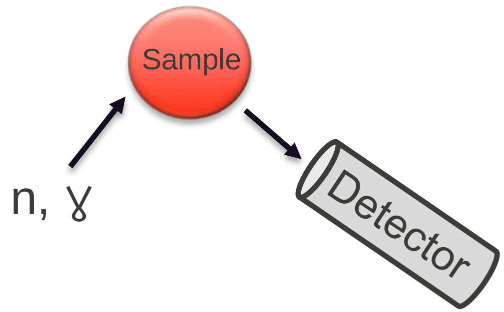
Termination of safeguards

Nondestructive Assay (NDA)

- **NDA is the most commonly employed technique for material accountancy**
- **A series of gamma or neutron detectors are typically used to measure radiation emitted from the sample of interest**
- **Energy, timing, and intensity of radiation may be correlated to isotope type and quantity in the sample**



Passive:
No external source



Active:
Neutrons or gammas irradiate source to magnify signal

- **Passive interrogation requires good signal intrinsic to sample (^{240}Pu, ^{252}Cf)**
- **Active interrogation requires fissile material or material prime for gamma interactions (^{235}U, ^{239}Pu)**

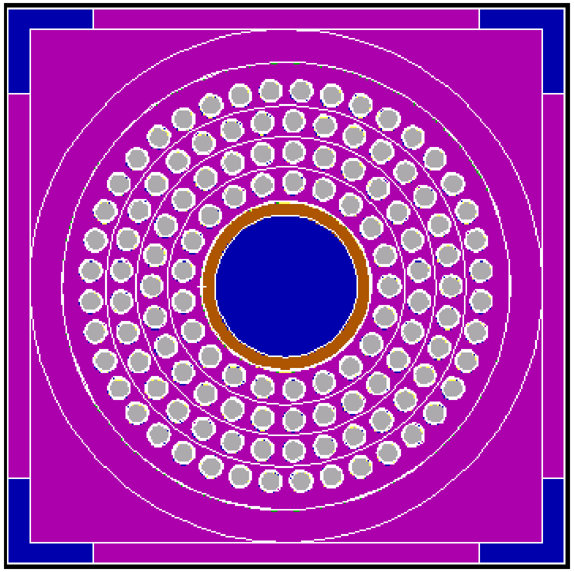
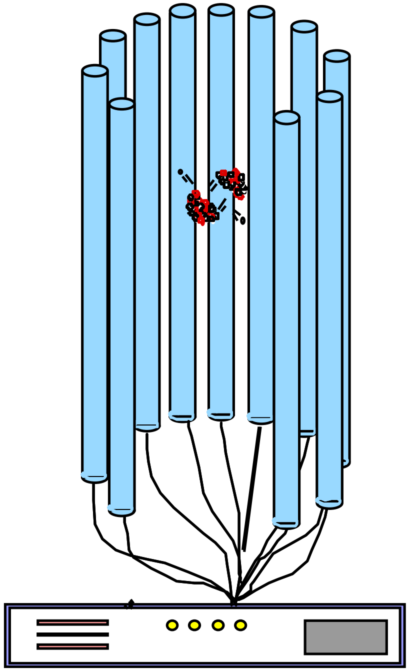
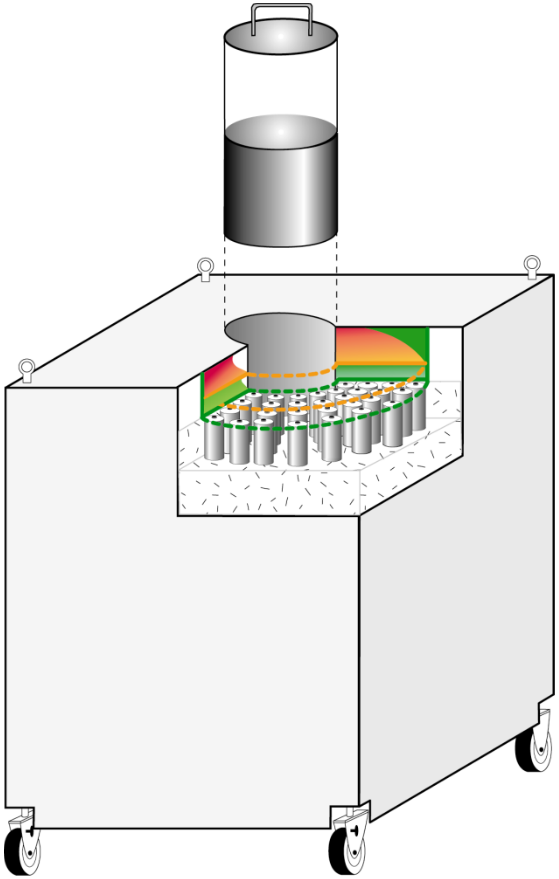
Rail radiation portal monitor (RPM) at the Port of Antwerp, Belgium

Neutrons and Photons

	Neutrons	Photons
Origins	– Spontaneous and induced fission – (α,n) – Cosmic rays – (p,n) – (n,2n) – (γ,n) (Cosmic rays, (p,n), (n,2n), (γ,n): Less common)	– Nucleus (gamma-ray) – Nuclear collision (gamma-ray) – Electron cloud (x-ray)
Signal	**Time and correlations**	**Energy**
Shielding	**Low Z material**	**High Z material**
Detectors	**^{3}He, Scintillators, fission chambers**	**HPGe, Scintillators, NaI**

Plutonium Mass Measurements

- Epithermal Neutron Multiplicity Counter (ENMC)
- Measure total number of neutrons, number of times two neutrons are detected close together in time (doubles) and number of times three neutrons are detected close together in time (triples)
- Solve point model equations, determine Pu mass

Spent Nuclear Fuel

- **The most complex nuclear material on earth**
- **With millions of neutrons and gammas emitted per second, it is extremely dangerous**
- **How do we measure something so incredibly complex and dangerous?**

A: We gather as much varying information as possible

- **Combine different signals**
  - Neutron count rate
  - Neutron timing
  - Gamma count rate
  - Gamma energy
  - Detector filters
- **Fork Detector is one of the spent fuel NDA techniques currently employed**
  - Utilizes gross gamma and gross neutron counts

Thank you!