

Nuclear Safeguards Non-Proliferation & History and Evolution

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Content of 2 lectures

Short history of nuclear safeguards & (non-)proliferation 11/12/20

(Credit for time-line of events : L. Rockwood (material presented at ESARDA courses))

+ Safeguards implementation under EURATOM (briefly 11/12/20)

(Credit for EURATOM slides : P. Schwalbach (material presented at ESARDA courses))

Safeguards/NP R&D challenges and JRC contributions on (early 21)

Analytical measurements

Reference Materials

Synergies with DWM

Containment & surveillance

Process Monitoring

Strategic Trade Control

Proliferation Resistance

Open Source & NP studies

Disarmament verification

Education and Training

+ Few words on nuclear security R&D (and EU outreach)

Introduction to nuclear safeguards

***WHY** was safeguards created?*

***WHEN** was safeguards created?*

***HOW** did safeguards evolve?*

***WHY** do we (still) need safeguards?*

***WHAT** exactly is safeguards ?*

***WHAT** is not included in safeguards?*

***WHERE** is safeguards implemented?*

***WHO** implements safeguards?*

***HOW** is safeguards implemented? (next lecture)*

***WHICH** are the shortcomings and challenges? (next lecture)*

Official Warning

Safeguards is

Too **political** for a technician
&

Too **technical** for a politician

Too **legal** for an engineer
&

Too much **engineering** for a lawyer

APPETIZER : Current Legal Basis for Nuclear Material Accountancy

Non-proliferation Treaty Article III:

“Procedures for the **safeguards** required by this Article shall be followed with respect to **source or special fissionable material** whether it is being produced, processed or used in any principal **nuclear facility or is outside any such facility**. The **safeguards** required by this Article shall be applied **on all source or special fissionable material in all peaceful nuclear activities** within the territory of such State, under its jurisdiction, or carried out under its control anywhere.”

Source or special fissionable (together “nuclear”) materials

Unat, Udepleted, Thorium

Pu-239; U-233; Uenriched in U-235 or U-233

Comprehensive Safeguards Agreement (INFCIRC 153)

National System Of Accounting For and Control of Nuclear Material

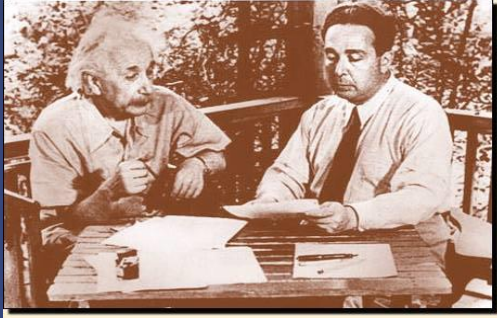
The Agreement should provide that the State shall establish and maintain a system of accounting for and control of ***all nuclear material subject to safeguards*** under the Agreement, and that such safeguards shall be applied in such a manner as ***to enable the Agency to verify***, in ascertaining that there has been no diversion of *nuclear material* from peaceful uses to nuclear weapons or other nuclear explosive devices, ***findings of the State's system***

What can IAEA conclude through implementing safeguards ?

- If, taking into account all available info, there are :
 - No indications of **diversion** of declared nuclear material
AND
 - No indications of **undeclared** nuclear material or activities
- IAEA can draw the broader conclusion:
 - **All nuclear material remained in peaceful activities**
- The subsequent safeguards implementation is determined by the safeguards conclusions (e.g. State level approach)

The First Twenty-Five Years: Creation of the IAEA and its Safeguards System

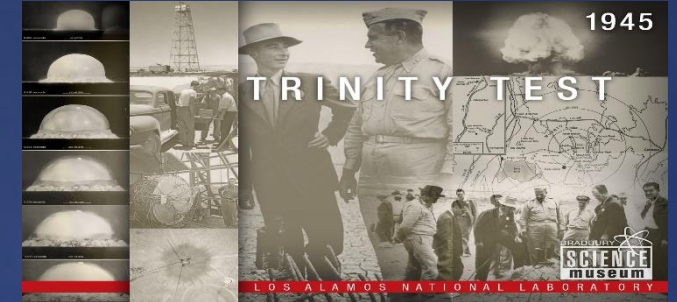
1939



1942

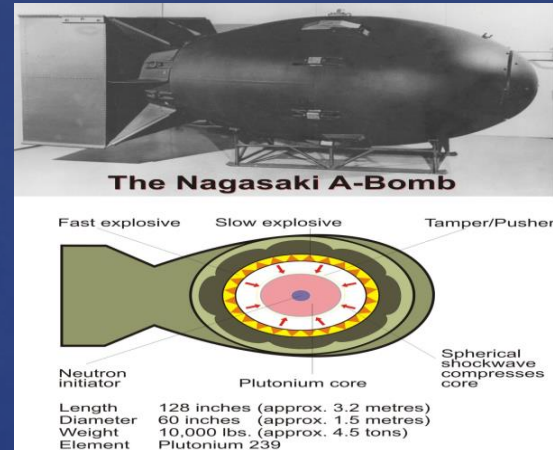


1945

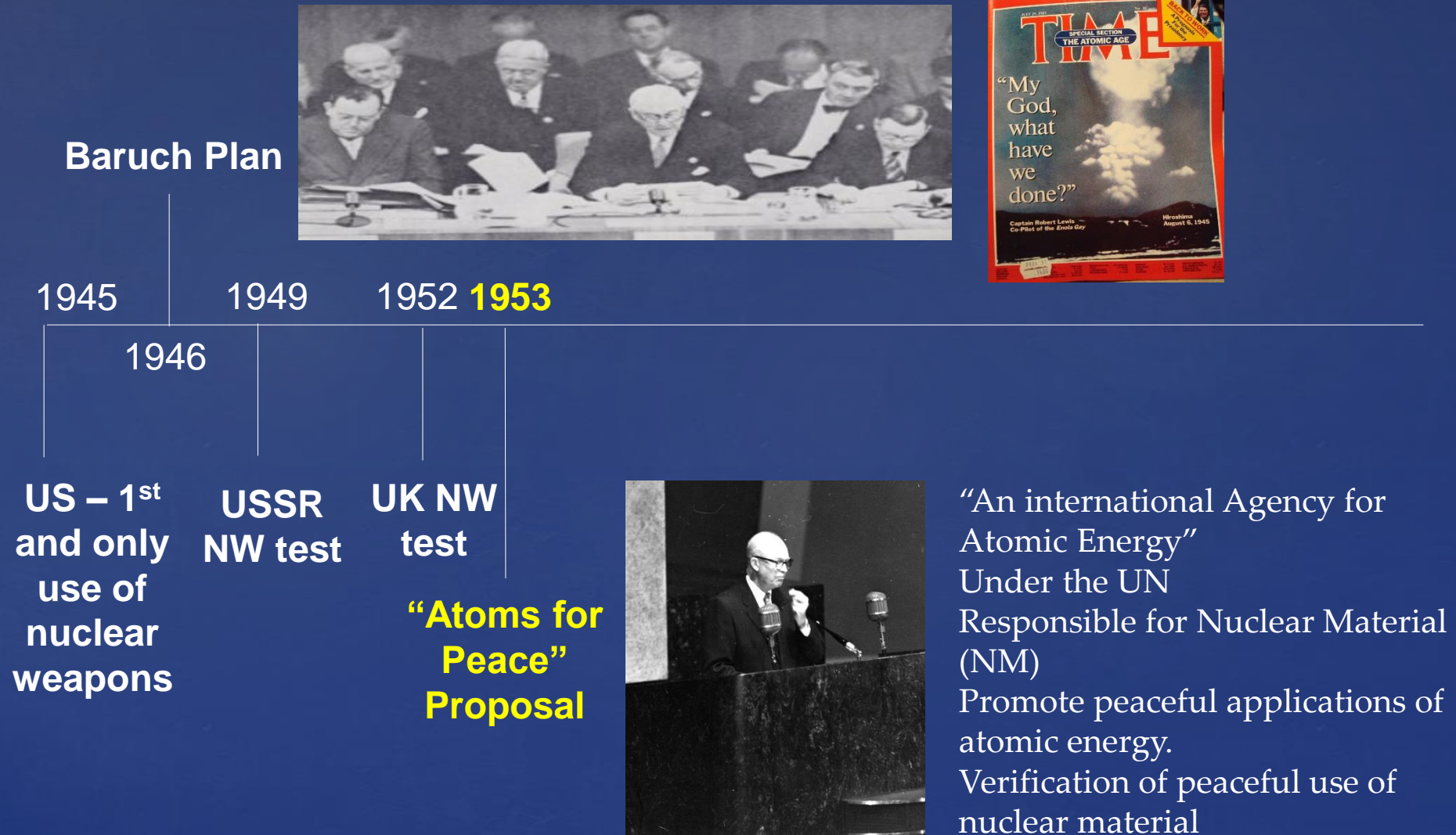


1945

US – 1st
and only
use of
nuclear
weapons



The First Twenty-Five Years: Creation of the IAEA and its Safeguards System

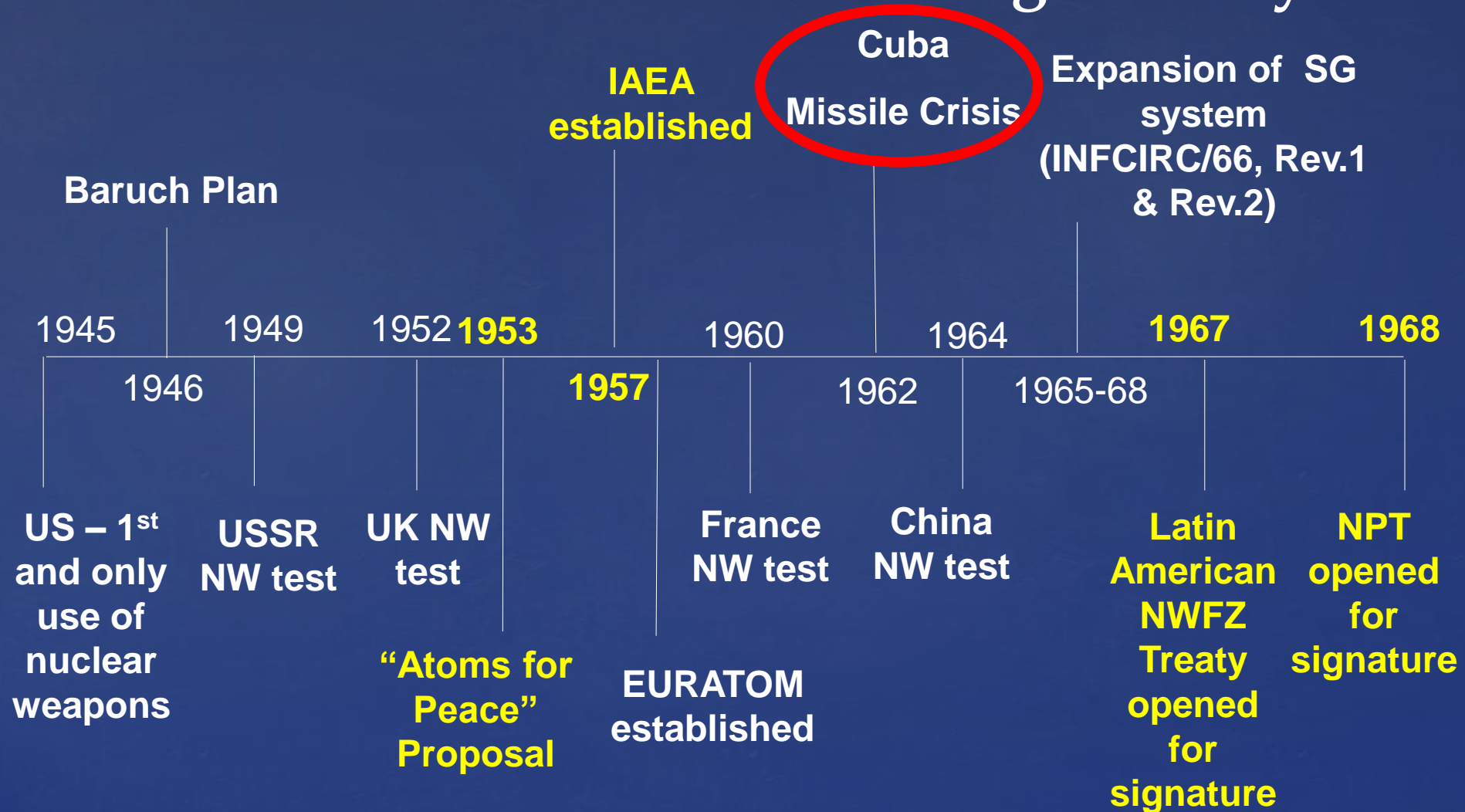


The First Twenty-Five Years: Creation of the IAEA and its Safeguards System



The First Twenty-Five Years:

Creation of the IAEA and its Safeguards System



CUBAN MISSILE CRISIS (simplified) "Most dangerous moment in human history"

Failed invasion of US funded exiles against Fidel Castro

SU supports ballistic missile deployment in Cuba

US Naval blockade against arrival of WMD

US Signalling depth charges dropped on SU submarine

2 out of 3 officers agree to nuclear launch

Vasily Alexandrovich Arkhipov says NO



The Following Two Decades: The Comprehensive Safeguards System

**NPT
enters
into
force**

1971



Nuclear-Weapon States (NWSs)

- Not to provide nuclear weapons or nuclear explosive devices to NNWSs (Art. I)

Non-Nuclear-Weapon States (NNWSs)

- Not to acquire nuclear weapons or other nuclear explosive devices (Art. II)
- Accept safeguards on all nuclear material (Art. III.1, 4)

1970

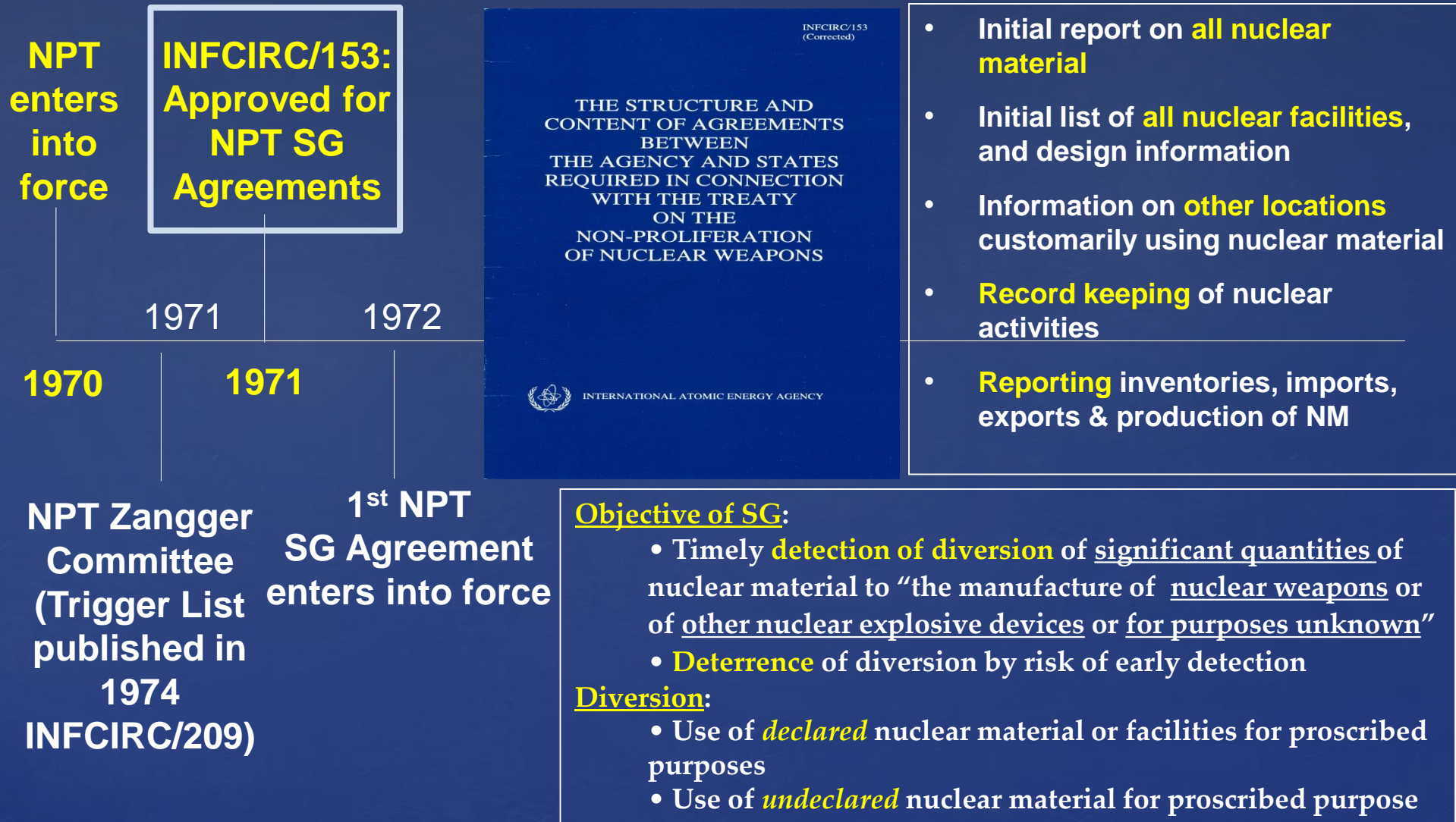
**NPT Zangger
Committee
(Trigger List
published in
1974
INFCIRC/209)**

- Informal Committee
Common understanding
of Art. III.2 of NPT
- Zangger “Trigger List”
Requires safeguards as a
condition for supply
- Composed by major
Nuclear Suppliers
48 States are members

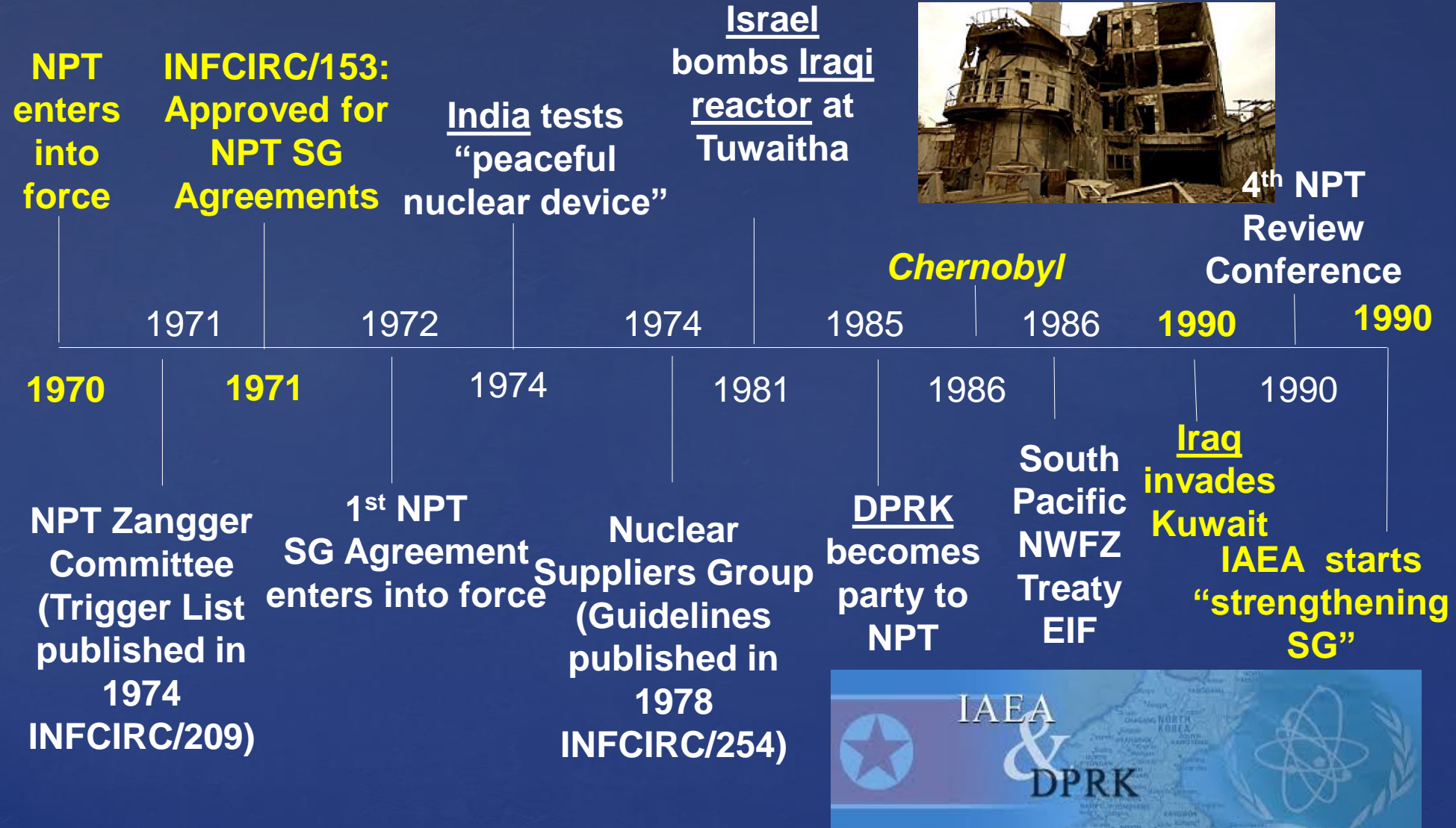
All States Parties

- Export controls: nuclear material; single use
items
(Art. III.2)
- Facilitate exchange of technology (Art. IV.2)
- Pursue negotiations on nuclear disarmament
(Art. VI)

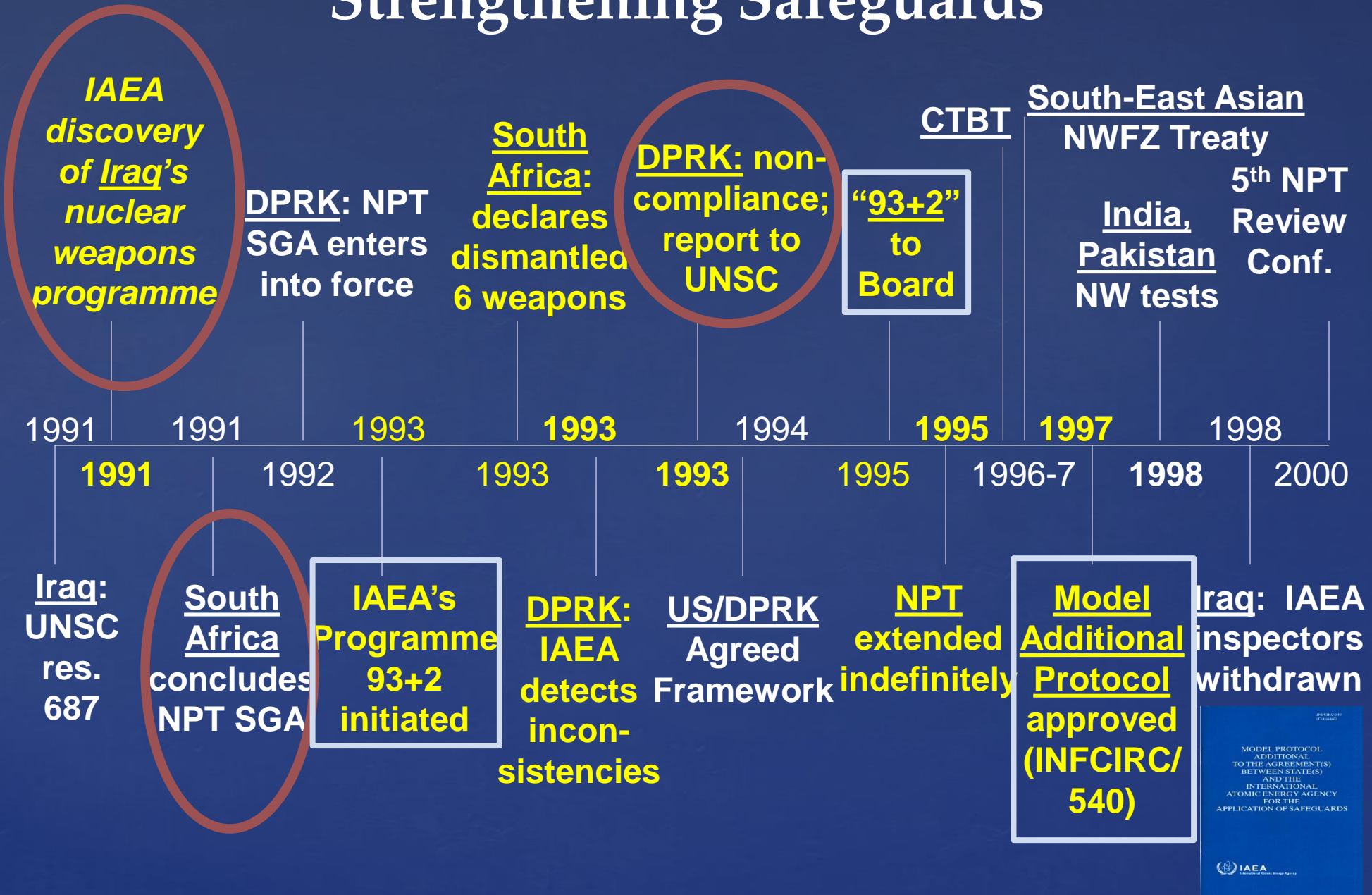
The Following Two Decades: The Comprehensive Safeguards System



The Following Two Decades: The Comprehensive Safeguards System

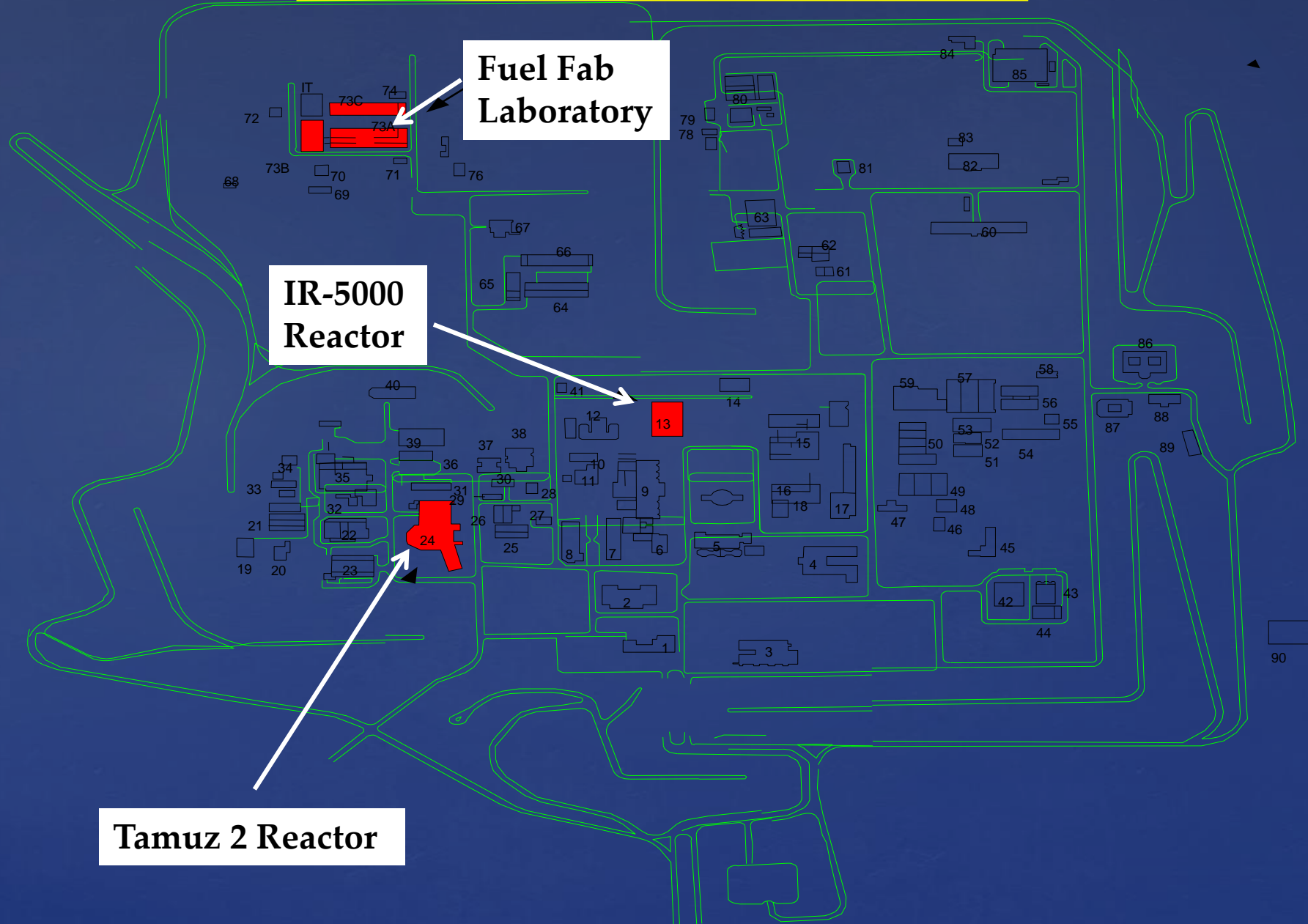


The Next Decade: Strengthening Safeguards



IRAQ TUWAITHA

Activities Declared Prior to 1991



**Fuel Fab
Laboratory**

**IR-5000
Reactor**

Tamuz 2 Reactor

Lessons Learned from the Discovery of Iraq's Clandestine Programme

Member States realized that:

- ⌘ Earlier limitations on IAEA to the verification of declared facilities and material undermined effective safeguards
- ⌘ Verification of the absence of clandestine activities is essential to providing the requisite degree of assurances

To achieve this, the IAEA safeguards needed to be strengthened (cf. Model Additional Protocol):

- ⌘ Broader access to information
- ⌘ Improved analysis of all types of information
- ⌘ Expanded access to locations, whether declared or undeclared



Source: J. Baute, "Iraq Case Study: 14 Years of Ongoing Challenges (April 1991-July 2005)", 16th ESARDA Course on Nuclear Safeguards and Non-Proliferation

South-African Nuclear Weapons Program (1)

Capability and nuclear fuel cycle:

- Large indigenous supply of U (by-product of gold mining), former US, UK supplier of U and substantial economic resources
- US Atoms for Peace program providing a research reactor, HEU fuel and training
- Secretly developed uranium enrichment process** (via an aerodynamic separation process), and mastered all aspects of a **complete indigenous nuclear fuel cycle**
- Sophisticated indigenous conventional armaments and aeronautical R&D
- Non-signatory to the NPT, covert development along with civilian NP**

Motivation for NW (from 1978):

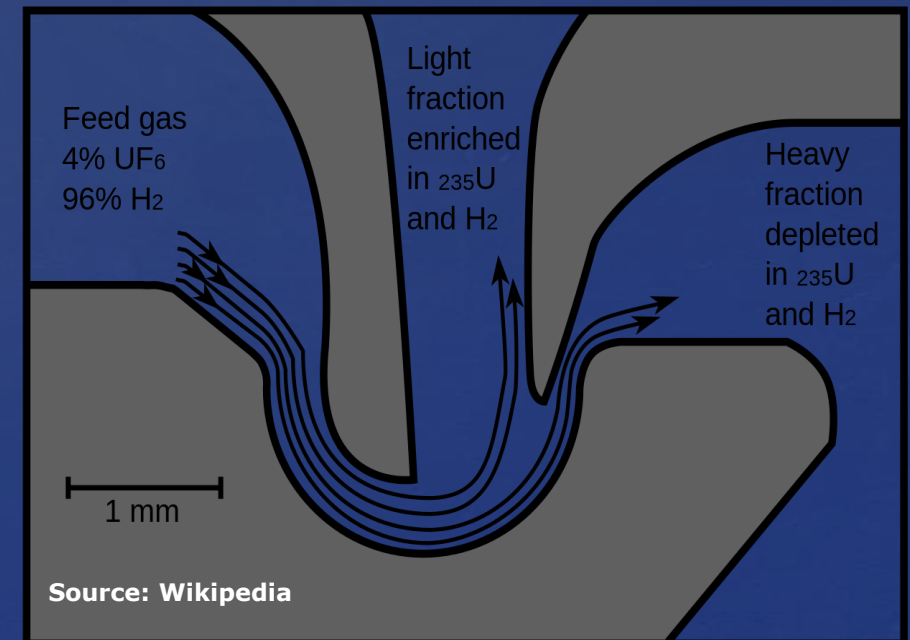
- Instability in the region: decolonization of Mozambique/Angola and Warsaw pact forces involvement, end of white rule in Rhodesia, pro-democracy demands (ANC)
- Nuclear deterrent against (a) possible proxy tactical nuclear attack, (b) acquisition of nuclear weapons by sub-national groups, (c) worldwide Cold war tensions
- 6 Nuclear Weapons developed**, foreseen for air-drop delivery

End of NW program (from 1989):

- Increased stability in the region, break up of Soviet union, regime change, end of white rule
- Nuclear weapons became superfluous for security purposes, and an obstacle to resumed international relations and obligations



Scheme of an aerodynamic nozzle, many thousands are needed in an enrichment unit



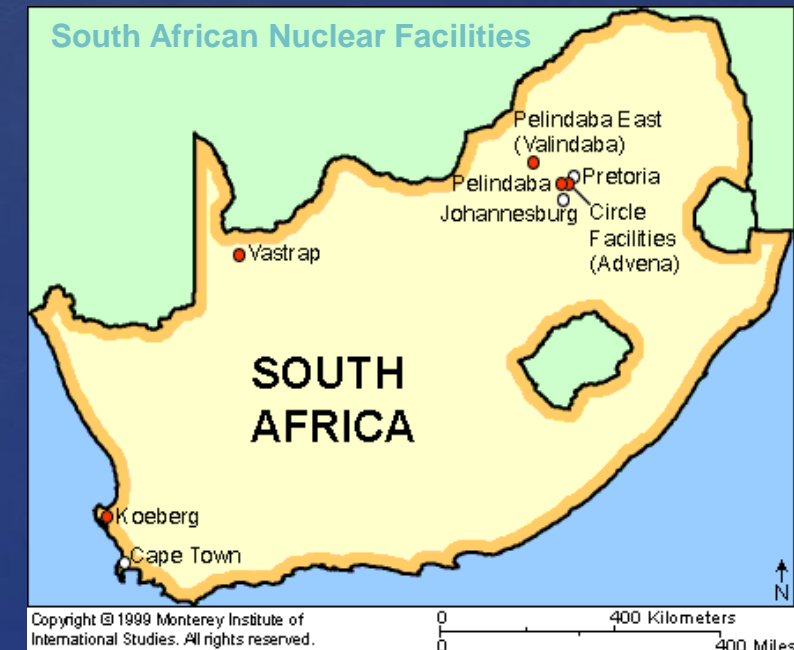
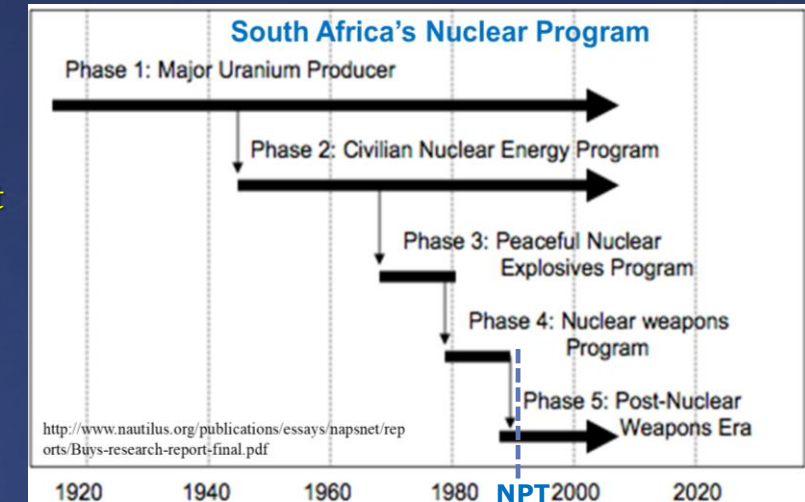
South-African NW Program (2)

Timeline of IAEA involvement:

- July-September 1991: South Africa signed the NPT and a Safeguards Agreement, but did not admit to having had 6+ nuclear weapons
- September 1991: IAEA Board & GC → DG to verify the completeness of South Africa's inventory nuclear installations and material
- IAEA activities began with the inventory of the Valindaba HEU stockpile and review of operating records to verify declarations
- Additional visits by IAEA to Vastrap nuclear test site and Pelindaba criticality facility, cover-stories and deception plans were used
- March 1993: South Africa succumbed to pressure and revealed the previous nuclear weapons program in March 1993
- The IAEA followed-up with onsite visits to nuclear weapons sites

Lessons learned:

- The IAEA acquired fundamental experience** on the field, which can be used in **disarmament verification** (first of a kind, useful for e.g. DPRK?)
- Use of IAEA visits** (then to become Complementary Access under Additional Protocol, Art. 4-10) i.a. to assure absence of undeclared material/activities, to confirm decommissioned status, to resolve questions/inconsistencies
- A State can voluntarily abandon a Nuclear Weapons program**, and have its absence verified by the International Community, when the economic (trade) and geopolitical benefit of complying with legal/political commitments outweighs the perceived security benefit of a nuclear option

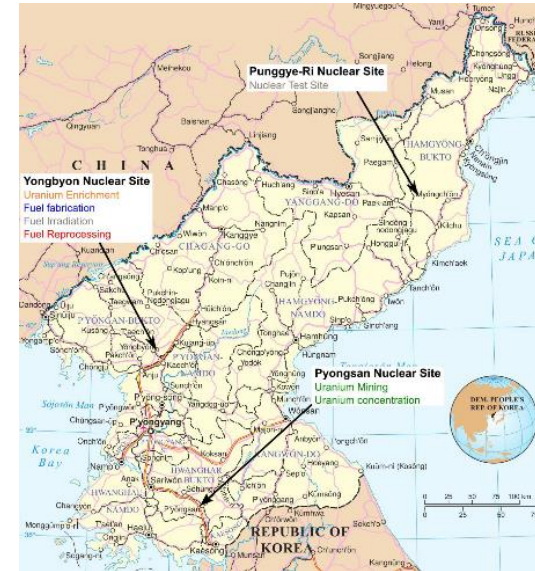


The DPRK Nuclear Programme

- **DPRK signed the Treaty on the Non-Proliferation of Nuclear Weapons (NPT) in 1985 and withdrew from the Treaty in 2003.**
- It has allegedly been working on a nuclear weapons programme since the early 1990s, covering:
 - production of weapons-grade plutonium and uranium
 - work on weaponization and underground nuclear testing
 - development of ballistic missiles for the delivery of a nuclear weapon.
- Its nuclear programme gained significant momentum since 2015, as testified by the timeline of both nuclear explosive and ballistic missile tests.
- The international community made several unsuccessful attempts to find an agreement with DPRK for dismantling the nuclear programme. E.g. the six-party talks, ended in 2009 when DPRK expelled the nuclear safeguards inspectors of the International Atomic Energy Agency (IAEA).
- On current US-DPRK talks there is lots of speculation in the news and thus there are not commented here



Timeline Sources:
The Economist, CNN,
IAEA



1985:
DPRK signs the NPT

1998:
Taepodong missile fired traversing Japan airspace

1994:
DPRK and US sign "Agreed Framework"

1993:
IAEA announces DPRK non-compliance with safeguards agreement
DPRK threatens to leave the NPT
1991:
First test of Nodong1 missile

2009:
Second DPRK nuclear test
Expulsion of IAEA inspectors and restart of nuclear facilities
Missile launches in violation of UNSCR
2007:
After round of Six-Party talks DPRK agrees to shut down nuclear facilities.
IAEA inspectors confirm the shut down of 5 facilities in Yongbyon

2006:
First DPRK nuclear test

2005:
After round of Six-Party talks DPRK agrees to abandon nuclear programme for sanctions reliefs
2003:
DPRK withdraws from NPT, reactivates nuclear facilities and announces it has nuclear weapons

2002:
DPRK expels IAEA inspectors from country

2018:
Meeting between DPRK and ROK leaders
DPRK closes its nuclear test site
Kim Jon-Un and Donald Trump agree to meet in Singapore

2017:
Sixth DPRK nuclear test
Several ballistic missile tests

2016:
Fourth and Fifth DPRK nuclear tests, claimed to be thermonuclear
Several ballistic missile tests, including from submarine

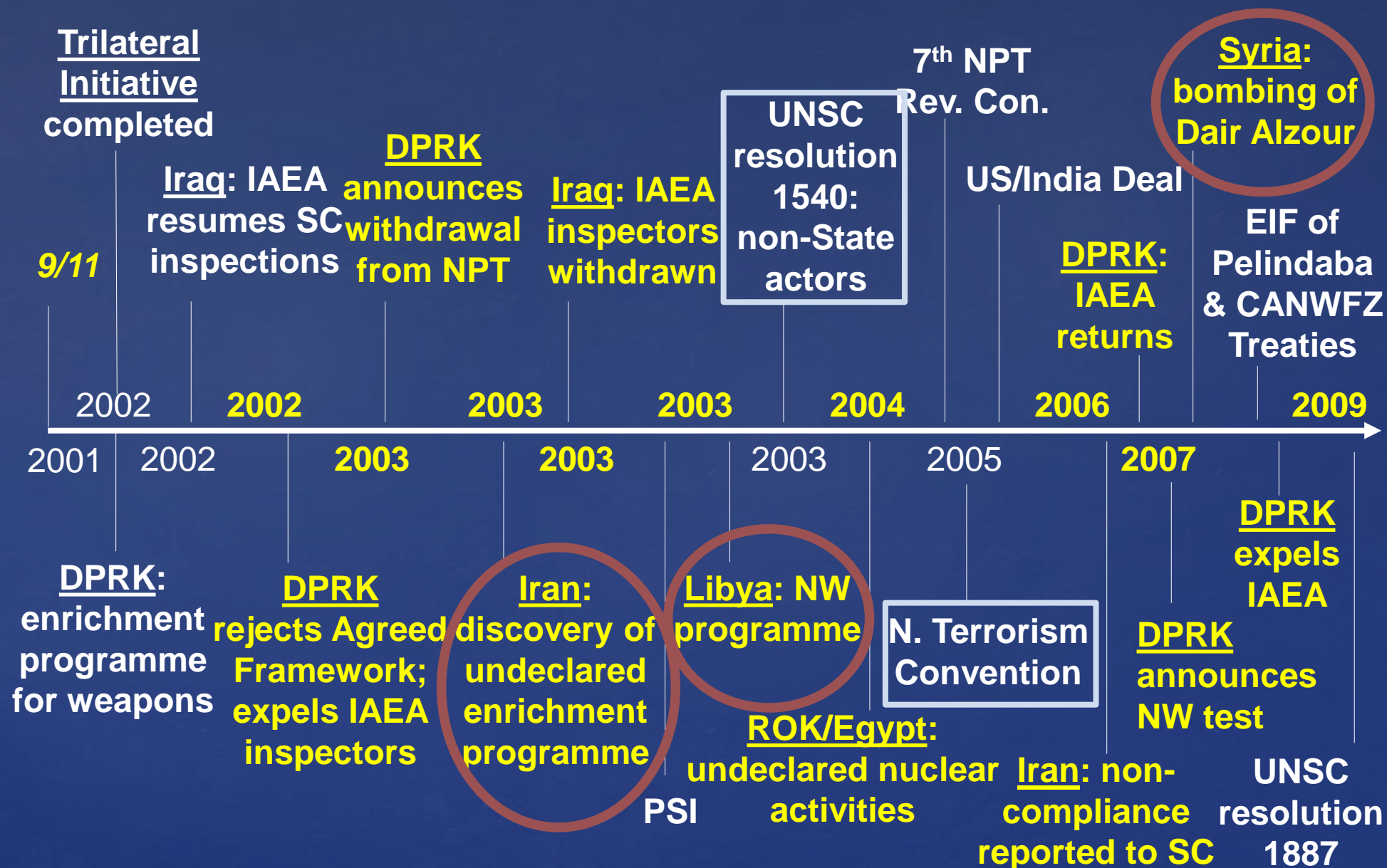
2013:
Third DPRK nuclear test

2012:
DPRK agrees on moratorium on long range missile tests, nuclear tests and enrichment
DPRK launches a satellite



1980s	1990s	2000s	2010s
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The Next Decade



Libyan Nuclear Weapons Program

Capability, nuclear fuel cycle and NW program:

- ↳ Very little infrastructure (Russian research reactor only)
- ↳ Ratified NPT in 1975, Safeguards Agreement in 1980. **Proliferator within NPT**
- ↳ Original drive of NW program: to develop a nuclear deterrent against Israel
- ↳ **Need of external assistance, lack of indigenous capabilities**
- ↳ Late 1970s-1980s, undeclared activities (import of UOC, attempts to acquire conversion facility, delivered in 1984 but not used)
- ↳ From 1980s: covert efforts to acquire gas centrifuges technology for uranium enrichments via foreign experts and **A. Q. Khan network**
- ↳ 2000s: material for three cascades of 1st generation Pakistani centrifuges delivered, a cascade installed, orders placed for 2nd generation machine

End of NW program:

- ↳ Ongoing intervention in Iraq to counter alleged Iraqi NW program
- ↳ October 2003, UK and US ships intercepted a German cargo ship heading to Libya from Dubai with a cargo of centrifuge parts
- ↳ December 2003, the Libyan regime officially abandoned all its NW program
- ↳ 2003-2008 Additional Protocol, IAEA verification, removal of material, closure of investigation

Lessons learned:

- ↳ Need of a robust export control regime and its enforcement
- ↳ Need to counteract illicit networks such as the A.O. Khan

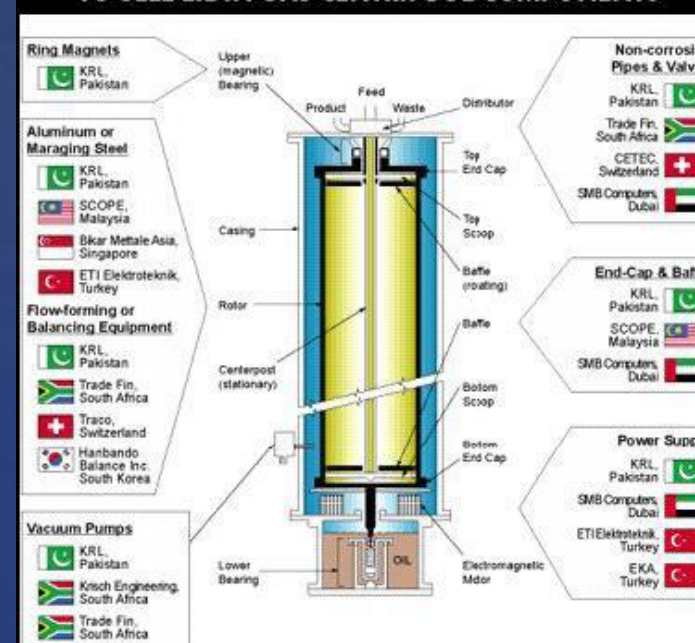


MV BBC China: diverted to Italy while carrying gas centrifuges to Libya in 2003 (source: Wikipedia)



Components of Libyan gas centrifuges surrendered to the US (source: Wikipedia)

COMPANIES REPORTED TO HAVE SOLD OR ATTEMPTED TO SELL LIBYA GAS CENTRIFUGE COMPONENTS



The Center for Nonproliferation Studies at the Monterey Institute of International Studies

CNS This graphic representation of the numerous countries involved -- generally without their knowledge -- in the Libya nuclear weapons program clearly demonstrates the need for tightening export controls as they relate to sensitive dual-use technology. **Disclaimer:** Information for this chart was taken from open press sources and unclassified government documents and are presented on an as-reported basis. The Center for Nonproliferation Studies cannot vouch for the accuracy or veracity of these reports.

Syria : Dealing with complex concealment solutions

The Al-Kibar Facility

- A Dair Alzour site in Syria was subject to an air strike in 9/2007.
- In the aftermath of the air strike, the claims that the destroyed site was hosting a nuclear reactor were disputed by some analysts on the grounds that many of the usual signatures associated to this type of facility were not evident.
- Others interpreted this absence as being the outcome of a complex concealment effort.
- In 2011 the IAEA assessed that “the destroyed building was very likely a nuclear reactor...”

Allegations of Secret Nuclear Sites

- In 2015, SPIEGEL ONLINE claimed that a secret underground nuclear facility (possibly an underground nuclear reactor or an enrichment facility) might be present in Syria (uncertain)

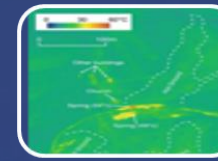
Lessons Learned

- ⌘ Need of studying the types of signatures associated to unusual technological options and how to detect them
- ⌘ An Unknown Known: Ground Source Cooling Systems

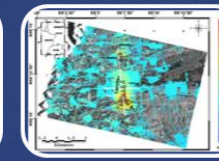
Source: Kim, L., Jungwirth, R., Renda, G., Wolfart, E., Cojazzi, G., “Potential Signatures and Means of Detecting a Hypothetical Ground Source Cooled Nuclear Reactor”, *Science and Global Security*, 2016.



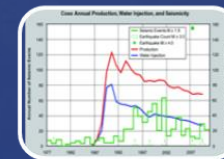
Visual



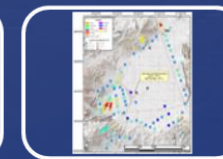
Thermal
Anomalies



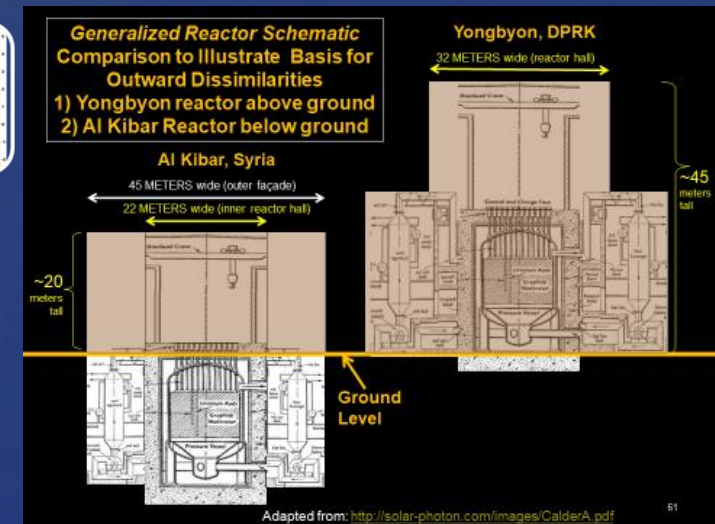
Geomorpho-
logical



Induced
Seismic



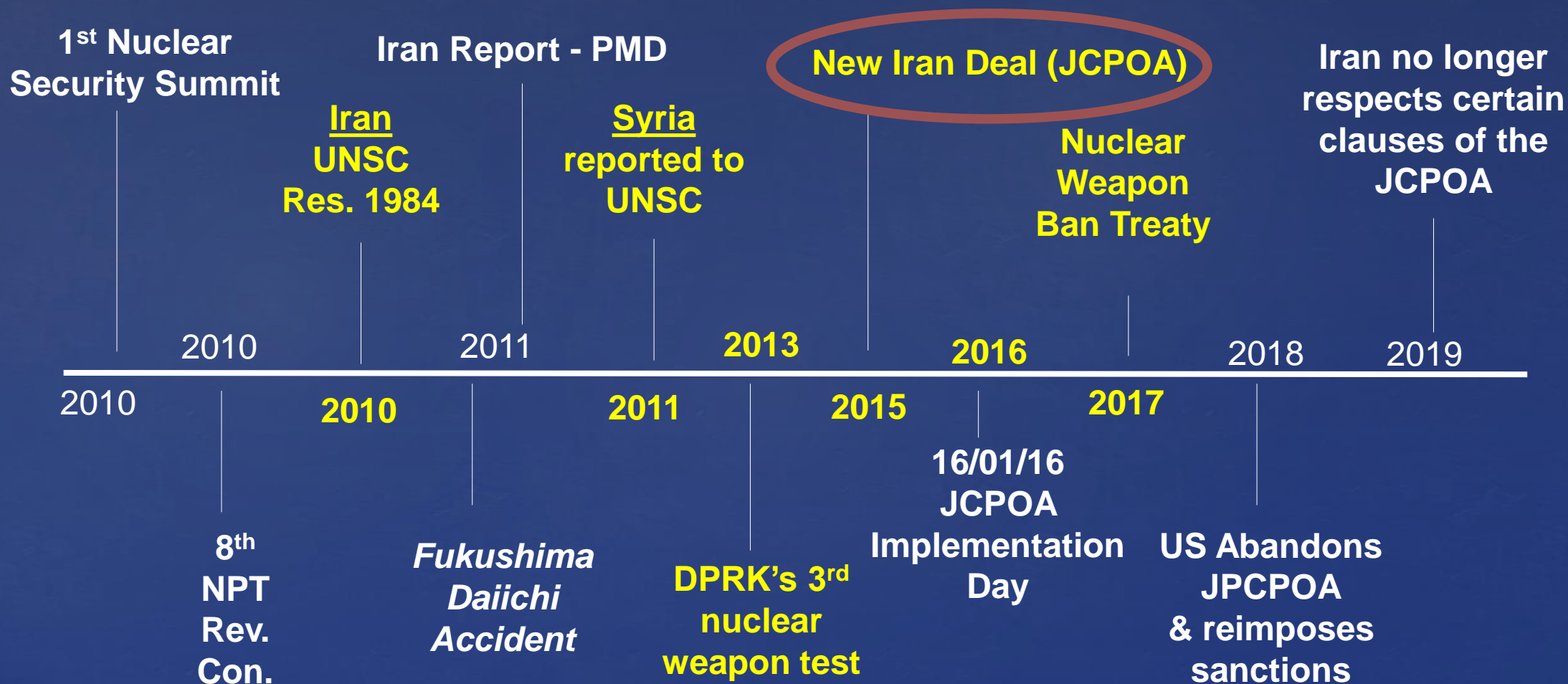
Chemical &
Radiological



Source: F. Pabian, “Open Source Tools for Nonproliferation Applications”, ESARDA Safeguards Training Course, JRC-Ispra, 2014

SOURCE: EC-JRC

The Last Decade



IRAN & PMD: 2011 – 2015



Model Additional Protocol

Additional Information

- All parts of the nuclear fuel cycle, not just nuclear material and facilities

Complementary Access

- To places beyond nuclear material and facilities
- Short notice (2/24 hours)
- Managed access to protect sensitive information

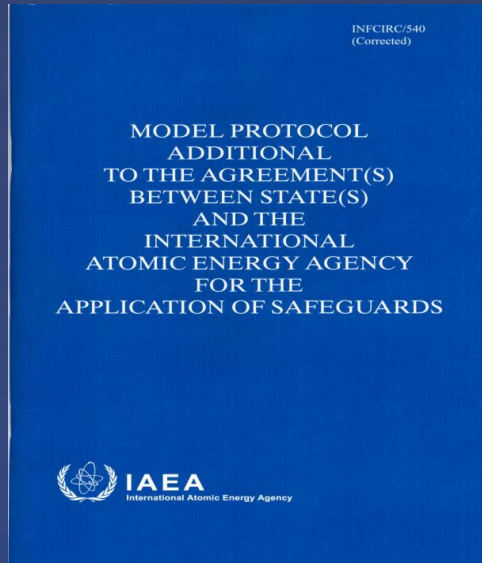
Administrative Measures

- Simplified inspector designation
- Reduced visa requirements

- **Sites of facilities/LOFs; other locations where nuclear material is located:** to assure the absence of undeclared nuclear material and activities
- **Decommissioned facilities/LOFs:** to verify decommissioned status
- **Other locations** in the State: to resolve a question or inconsistency – after consultation with the State

- Nuclear fuel cycle related **research and development**
- All locations on **sites** of facilities
- **Manufacture/assembly** of nuclear-related equipment
- Uranium **mines** and concentration plants
- Information on **other nuclear material** not reported under the Safeguards Agreement (e.g. exempted material)
- **Exports and imports** of specified items
- Long-term nuclear fuel cycle **plans**

AP and Export Control



- If, taking into account all available info:
 - No indications of diversion of declared nuclear material AND
 - No indications of undeclared nuclear material or activities
- IAEA can draw the broader conclusion:
 - All nuclear material remained in peaceful activities
- And implement more tailored SG for the State: the first “**State-level approaches**”

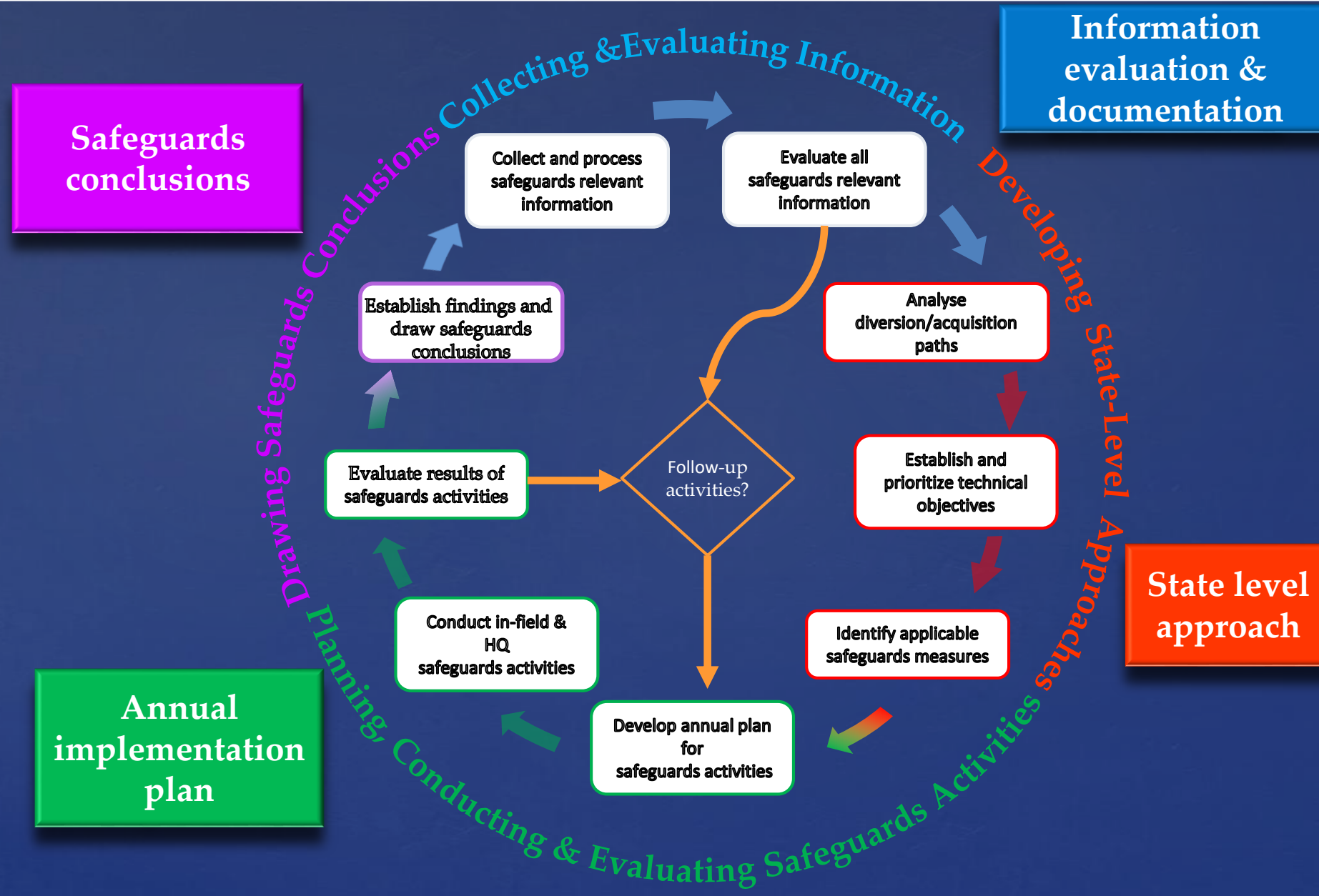
INFCIRC/254:

- Part 1 (1978): “EDP” items, and technology transfer
- Part 2 (1992): Dual-use equipment, material and technology
- Conditions:
 - ❖ “Full scope” SG as condition for future supplies (1992)
 - ❖ Exchange within NSG of notifications of denials

INFCIRC/539 (Rev.6): Outreach activities

1997: “The Nuclear Suppliers Group: Its Origins, Role and Activities” – revised in 2000, 2003, 2005, 2009, 2012 & 2015

IAEA State-Level Concept



Small overview of safeguards under the EURATOM Treaty – credit P. Schwalbach (ESARDA courses)

25.3.1957 Signature of the treaty founding the
European Atomic Energy Community - Euratom

by Belgium, France, Germany, Italy, Luxembourg and The Netherlands





Legal Structure of the European Union

**European Union
(TEU, TFEU, Charter)**

EURATOM

Treaty on the European Union (TEU)

Treaty on the Functioning of the European Union (TFEU, ex-EC)

Treaty of Lisbon

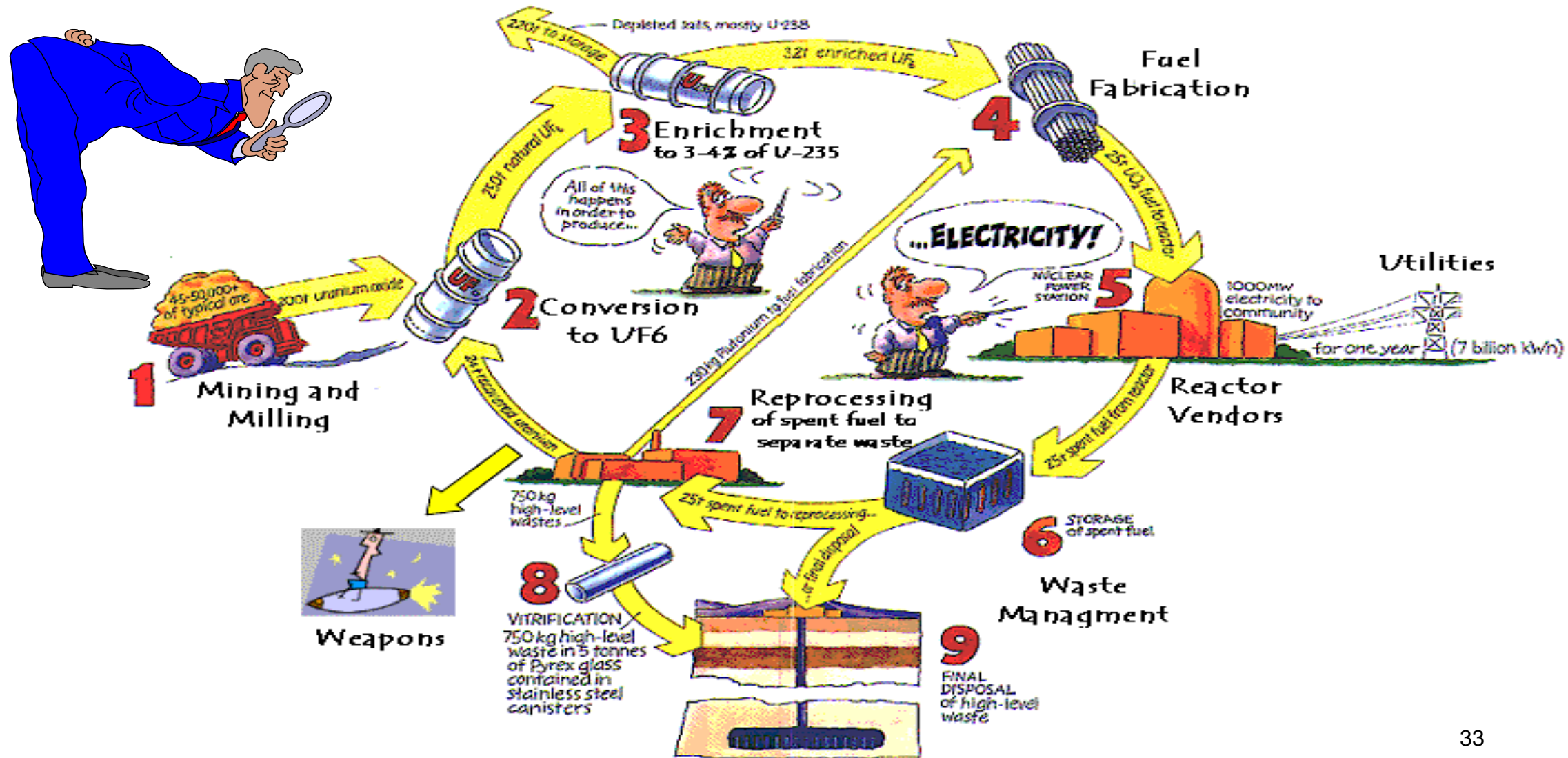


**Euratom
Treaty**
(Chap VII: safeguards)

- **Regulation No 302/2005**
*for the implementation of
Euratom Safeguards*
- **Particular Safeguards Provisions**
(Facility Specific)

- Commission Recommendations**
- *on the application of Safeguards Regulation
(2006/40/Euratom)*
 - *on Nuclear Material Accountancy and Control Systems
(2009/120/Euratom)*

The fuel cycle



Conformity control:



Three Types



■ *Compliance control*

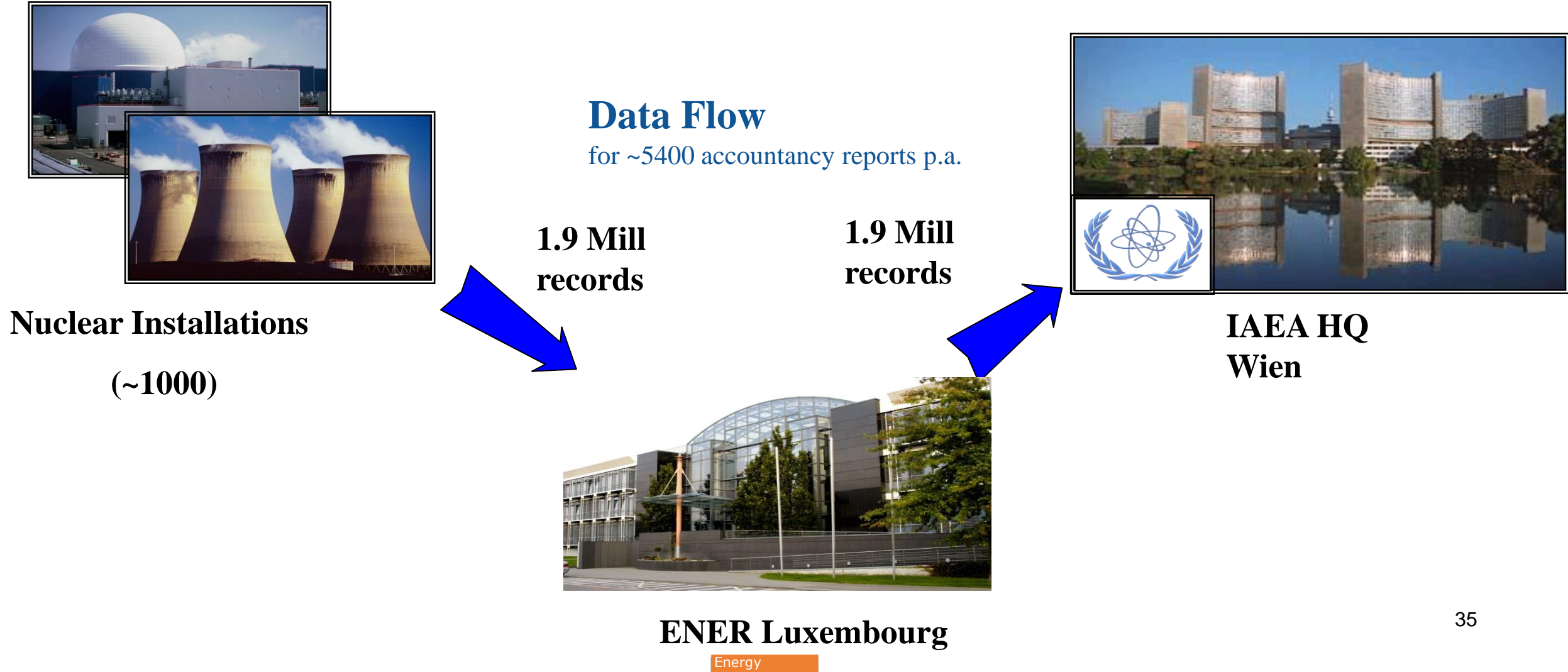
- Accounting checks (what-where-when)
- BTC declaration verifications

■ *Performance control*

- NMAC system quality auditing

■ *Credibility control*

- Physical verifications (measurements)



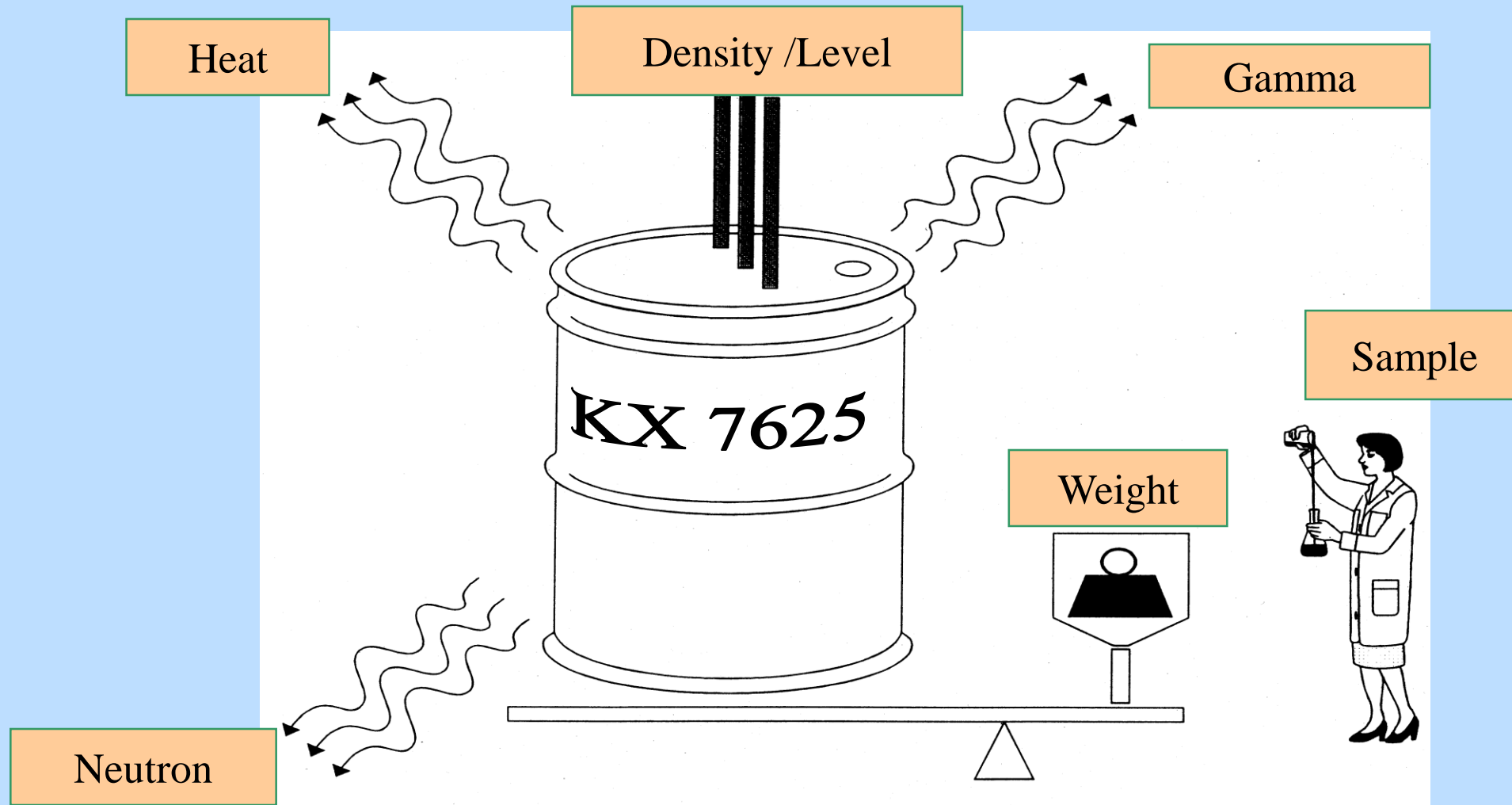
■ *Inspector analyses books: accounting*

- **Material balance records**
- **Inventory change reports**
- **Operating records**
- **MUF calculation**



■ *Inspector verifies Basic Tech. Characteristics (BTC), & process/construction modifications*

■ *Inspector physically verifies nuclear material*



(see also presentations on NDA&DA)

- **Verification is expensive !**
- **Preserve knowledge gained by verification measurement !**
- **For static situations material is contained and placed under surveillance (e.g. in storages)**
-

Use of cameras, seals, radiation monitors...

To reduce physical verification efforts

To reduce inspection intrusiveness





- EU has a sturdy far reaching legal framework for Nuclear Material control which is fully implemented – also in NWS !
- The EU system: strong platform enabling IAEA NPT role
- The implementation rests on three types of control:
 - **Control that nuclear operators adhere to reporting obligations**
 - **Control that operators run a high performance NMAC system**
 - **Ensure the credibility of the reports by physical verification**
- No evidence of NM diversion: -> deterrence works !??
(no evidence of diversion is NOT evidence of no diversion !)

Conclusion

You learned about safeguards, its origin and evolution over time.

You understand why, what, who & where safeguards is implemented.

You got some insights about the origin, mandate and role of IAEA in safeguards

You got a short indication of the EURATOM implementation of safeguards

In the next session you will learn more about: HOW, Tools, R&D & challenges in safeguards

Now : Q&A (not recorded) and for future questions : willem.janssens@ec.europa.eu