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Non-Proliferation Introduction to Safeguards

Uwe Georg, Swiss Federal Office of Energy (SFOE)

Non-Proliferation in Switzerland, EPFL, 07 November 2025

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CONTENT

Non-proliferation overview (07.11.2025)

- The basic problem
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Practical application of safeguards in Switzerland (12.12.2025)

- Nuclear landscape in Switzerland
- Legal basis in Switzerland
- Safeguards Measures by the IAEA
- Statistics and IAEA conclusions for Switzerland
- Export controls



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The basic problem

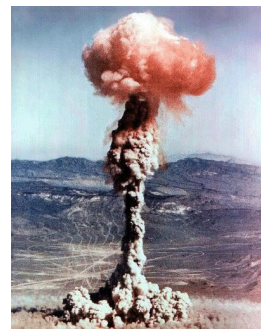
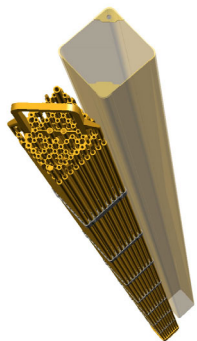
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NUCLEAR ENERGY AS A DOUBLE-EDGED SWORD (1)

Nuclear energy can be used both for peaceful and military purposes.
Source material for both applications is the same.

uranium (U) or plutonium (Pu)



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NUCLEAR ENERGY AS A DOUBLE-EDGED SWORD (2)

Nuclear material for both applications is the same, but

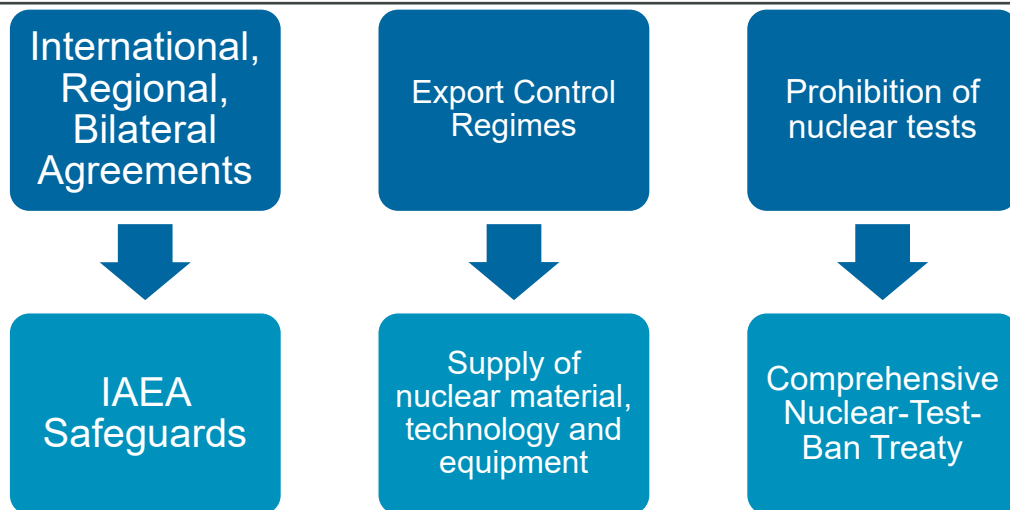
| Nuclear fuel | Nuclear bomb |
|--|-------------------------------------|
| 3 - 5 % (LEU), 10% (LEU+), <20% (HALEU) U-235 or mix of Pu-isotops + uranium (MOX) | ≥ 90 % U-235 or “pure” Pu-239 |

- Natural uranium
 - 99.3 % U-238 (not fissionable)
 - 0.7% U-235 (fissionable) → Need to enrich U-235
 - No plutonium in nature
 - Bred in reactors and then separated
 - Many processes and equipment used are identical or very similar for peaceful and for military purposes
- Need to control both **nuclear material** and **nuclear technologies**

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THE NUCLEAR NON-PROLIFERATION REGIME



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Historical overview

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EARLY SAFEGUARDS EFFORTS



Immediately after the end of the Second World War the USA had a monopoly on nuclear weapons and was addressing the proliferation of nuclear technology due to fears of future outside threats.

Baruch-Plan of 1946

First attempt for a global solution to prevent the spread of nuclear weapons

- Prohibition to possess, manufacture or use nuclear weapons
- Establishment of an international agency with complete control over all nuclear activities
- Failed mainly due to resistance from the USSR fearing a US nuclear monopoly until such an agency would have been established



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ATOMS FOR PEACE

- **1953**
 - Speech by President Eisenhower at the United Nations in New York: Atoms for peace (peaceful use of nuclear energy). This was the impulse for the creation of the International Atomic Energy Agency (IAEA).
- **1955**
 - First international conference on nuclear energy in Geneva (Switzerland bought the research reactor exhibited there, “Saphir”).
- **1957**
 - The IAEA was established in Vienna.



At that time countries seeking access to the peaceful use of nuclear energy had to conclude bilateral/trilateral agreements (e.g. USA-CH / USA-CH-IAEA [for NPP Beznau and NPP Mühleberg]).



INTERNATIONAL ATOMIC ENERGY AGENCY (IAEA)



- Objectives (Art. II)
 - Enlarge contribution of nuclear energy to peace, health and prosperity
 - Ensure nuclear technology is not used to further any military purpose
- IAEA statute:
 - Defines nuclear material (Art. XX):
 - “Source material”: natural uranium, uranium depleted in U-235, thorium
 - “Special fissionable material”: Pu-239, U-233, uranium enriched in U-235 or U-233
 - Authorizes the IAEA to establish safeguards (Art. III) to assure that material provided is not used for military purposes



STILL PROLIFERATION FEARS PERSISTED

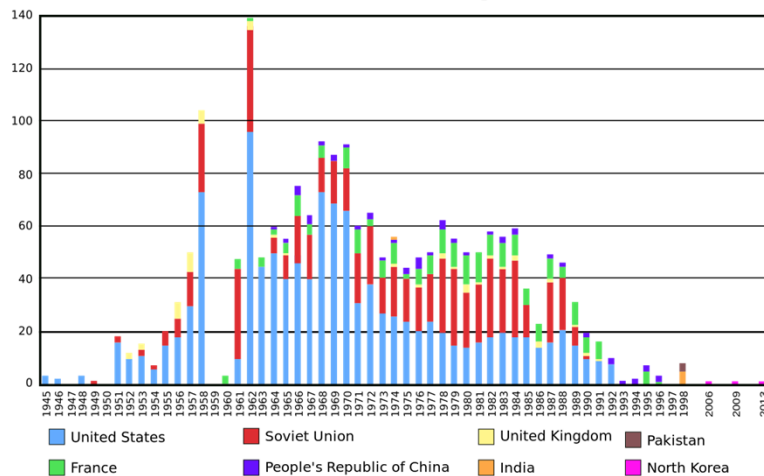
- 1960
 - "There are indications because of new inventions, that **10, 15, or 20 nations** will have a nuclear capacity [...] by the end of the Presidential office in 1964" (John F. Kennedy, Third Kennedy-Nixon Presidential Debate, 13 October 1960)
- Questions:
 - Has this come true?
 - Which countries possess nuclear weapons today?
 - Which other countries have embarked on nuclear weapons programs but do not possess nuclear weapons today?

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NUCLEAR TESTS

Worldwide nuclear testing, 1945 - 2013



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NUCLEAR TEST OVER TIME



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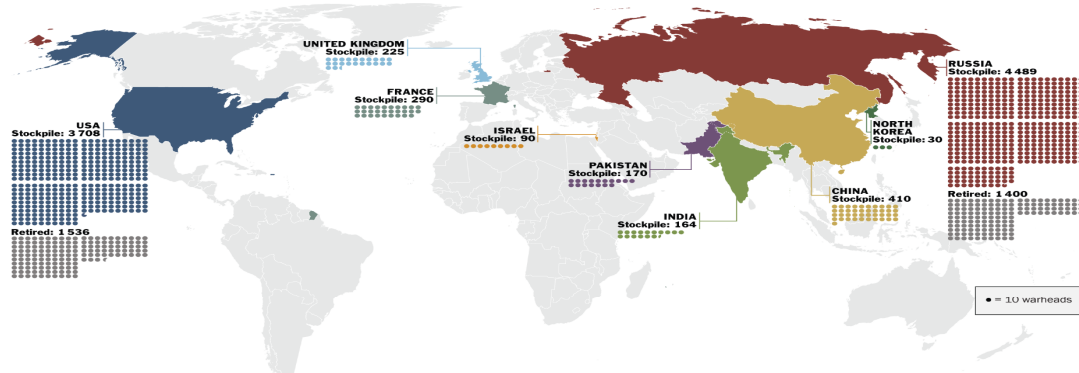
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NUCLEAR WEAPON STATES TODAY

GLOBAL NUCLEAR WEAPON NUMBERS, 2023



Notes: SIPRI revises its world nuclear forces data each year based on new information and updates to earlier assessments. The data for Jan. 2023 replaces all previously published SIPRI data on world nuclear forces. 'Stockpile' refers to warheads that are intended for use by the armed forces. 'Retired' refers to warheads that are retired from military service and scheduled to be dismantled but remain part of the overall inventory. As of Jan. 2023, SIPRI estimates that only Russia and the USA had significant numbers of retired warheads. Information about the status and capability of North Korea's nuclear arsenal comes with significant uncertainty. North Korea might have produced enough fissile material to build 50-70 nuclear warheads; however, it is likely that it has assembled fewer warheads, perhaps around 30. The boundaries and names shown and the designations used in this map do not imply any endorsement or acceptance by SIPRI.

Source: SIPRI Yearbook 2023.

Source: SIPRI Yearbook 2023

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Treaty on the Non-Proliferation of Nuclear Weapons

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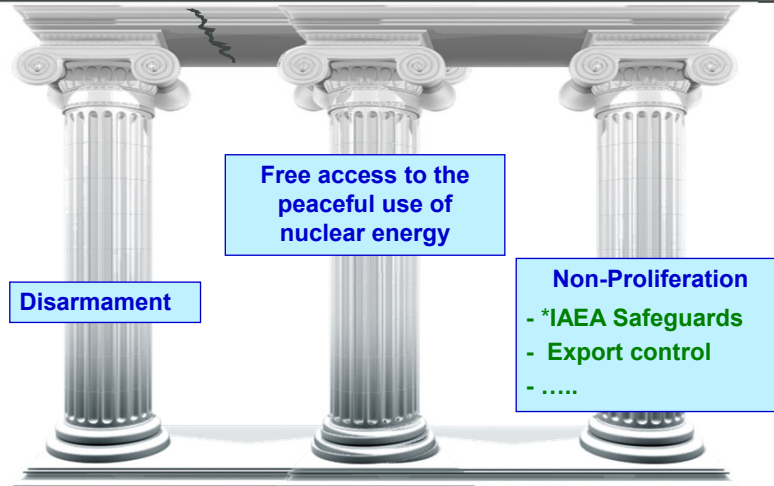
Treaty on the Non-Proliferation of Nuclear Weapons (NPT)

- Entered into force 5 March 1970 and extended indefinitely in 1995
- Only 5 pages and 12 articles
- Divides countries into:
 - Nuclear-weapon states (exploded a nuclear device before 1 January 1967)
 - Non-nuclear-weapon states (all other states)
- Establishes “3 Pillars” of the NPT:
 - Nuclear disarmament (nuclear-weapon states)
 - Peaceful use of nuclear energy (every state)
 - Non-proliferation measures/Safeguards (non-nuclear weapon states)

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THREE PILLARS OF THE NPT



* Comprehensive only in Non-Nuclear Weapon States

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Review of the fuel cycle

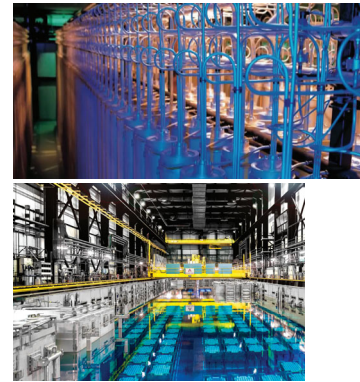
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NUCLEAR FUEL CYCLE



Of particular interest are enrichment and reprocessing capabilities.



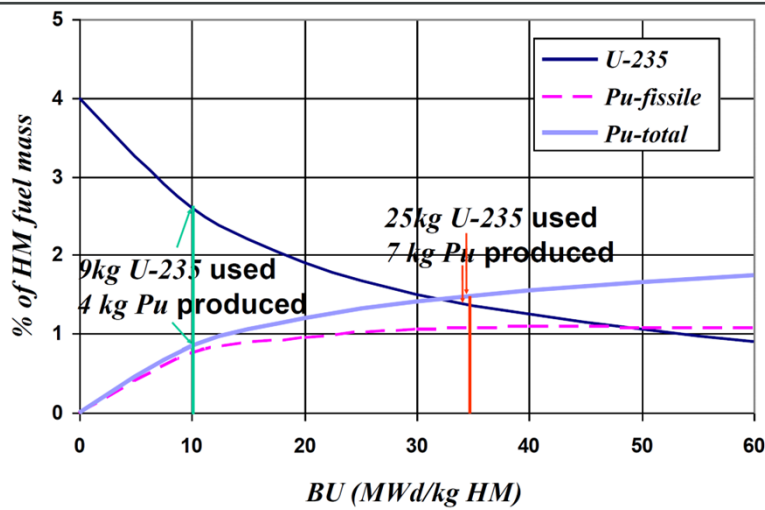
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NUCLEAR FUEL CYCLE



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Different legal instruments for IAEA safeguards

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VOLUNTARY OFFER AGREEMENT (VOA)

- A Safeguards agreement between the IAEA and a NPT-nuclear weapon state
- All five NPT-nuclear weapon states have signed one
- The state offers, for selection by the IAEA, to place some or all of its peaceful nuclear material and/or facilities under safeguards.
- The scope is not comprehensive.
- The offer can be altered by the state

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ITEM-SPECIFIC SAFEGUARDS AGREEMENT

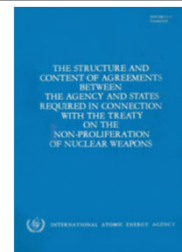
- IAEA document INFCIRC/66
- The classic safeguards agreement before the NPT
- Covers only materials specifically mentioned in the respective safeguards agreement
- Still applied in India, Israel and Pakistan (non-NPT parties)

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COMPREHENSIVE SAFEGUARDS AGREEMENT (CSA)

- Established in 1970 (INFCIRC/153)
- Main provisions:
 - **All nuclear material** must be under IAEA safeguards.
 - Detailed accounting of nuclear materials (**no threshold**).
 - **Inspections** of nuclear material and facilities by the IAEA.
 - Establishment of a **National Authority (SSAC)** responsible towards the IAEA (Safeguards section of the Swiss Federal Office of Energy, SFOE)



➤ Goal of the CSA

Assurance that all nuclear material is declared and not diverted for unauthorized purposes.

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LIMITATIONS UNDER THE CSA



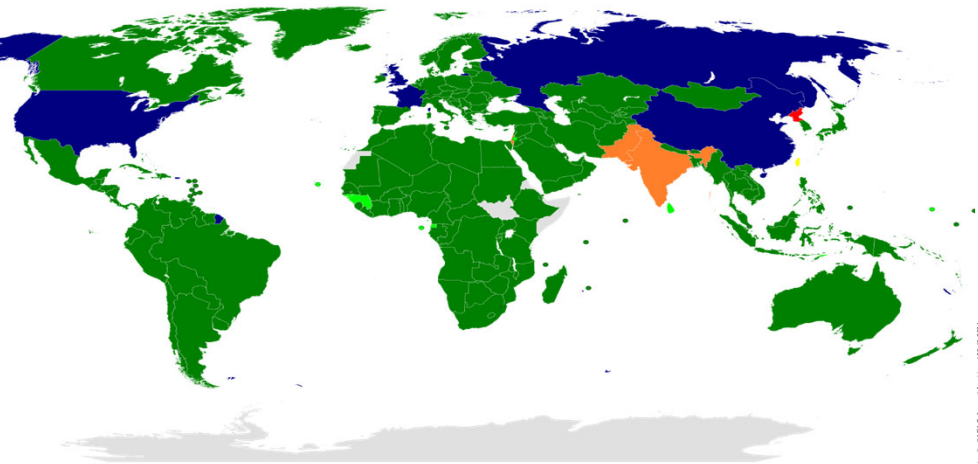
- Reporting focuses only on nuclear material.
- Routine inspections restricted to declared nuclear material and facilities.
- Verification addresses mainly the correctness of the State declarations.
- Difficult to confirm the absence of undeclared nuclear material and activities.
- Lack of comprehensive “state picture”.

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MAP OF SAFEGUARDS AGREEMENTS

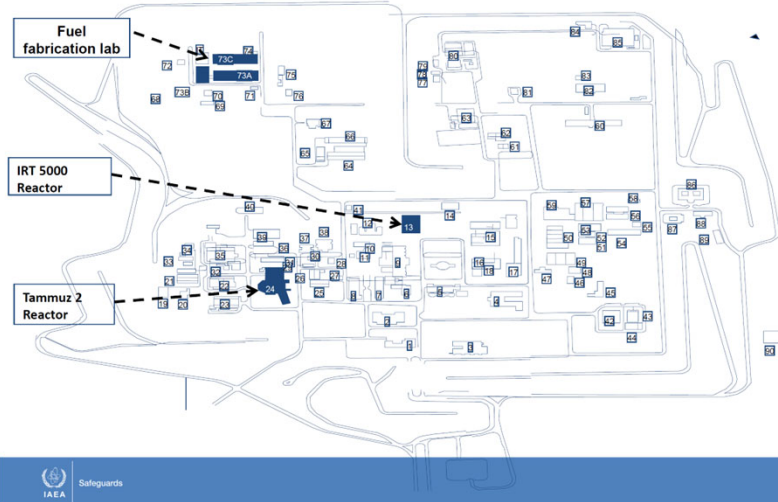
Blue: VOA with NPT nuclear-weapon state
Green: CSA in force/signed
Orange: Item-specific agreements
Red: Non-compliant with CSA in force
Yellow: Partially recognised with CSA in force



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IAEA Safeguards Legal Framework 2019

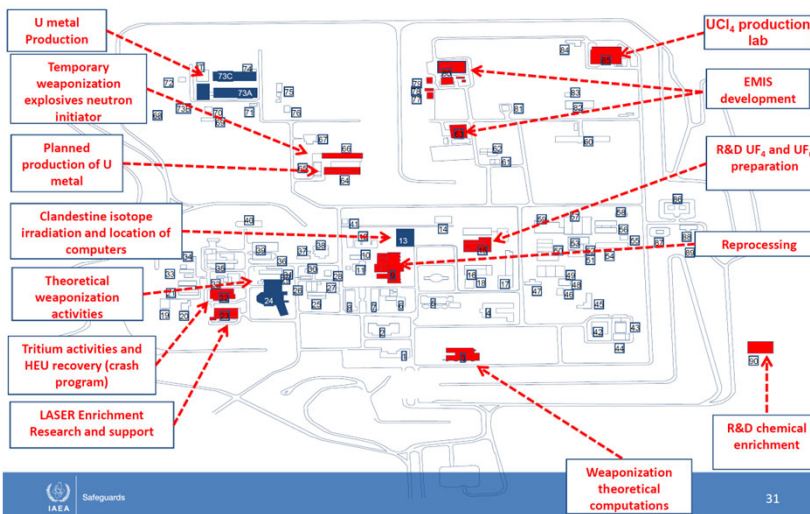
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TUWAITHA NUCLEAR RESEARCH CENTER



IAEA Safeguards Legal Framework 2019

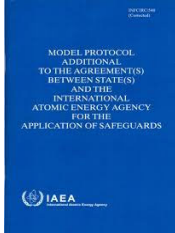
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ADDITIONAL PROTOCOL (AP) TO THE CSA



An additional protocol (AP) to a CSA provides:

Broader access to information





- A State's nuclear fuel cycle research & development activities 
- All parts of a State's nuclear fuel cycle, from uranium mines to nuclear waste 
- Manufacturing & export of sensitive nuclear-related equipment & material 



Broader access to locations



- Any place on a site at short-notice (2-hour or 24-hour access)
- Locations declared by the State under the Additional Protocol 
- Other locations specified by the Agency for the collection of environmental samples 

The measures provided for under an AP significantly increase the Agency's ability to verify the peaceful use of all nuclear material in a State with a CSA.



INFORMATION REQUIRED BY THE AP (1)

On Nuclear Material

- Domestically produced source material (includes mining of uranium and concentration of uranium and thorium).
- Imports/exports of source material for non-nuclear purposes.
- Locations and uses of exempted material.
- Locations of waste containing terminated special fissionable material.



Art. 2a. (v) / (vi) / (vii) / (viii)



INFORMATION REQUIRED BY THE AP (2)

On nuclear-related facilities and activities

- Description (dimensions + function/use) of every building belonging to a declared facility.
- R&D in the nuclear field (state sponsored and private) not involving nuclear material (exception basic research).
- Information about some (“nuclear”) industrial activities (Annex I).
- Uranium mining and uranium and thorium concentration plants.
- Exports (imports) of nuclear-related equipment and non-nuclear materials (graphite and heavy water).
- Future nuclear plans of a state.

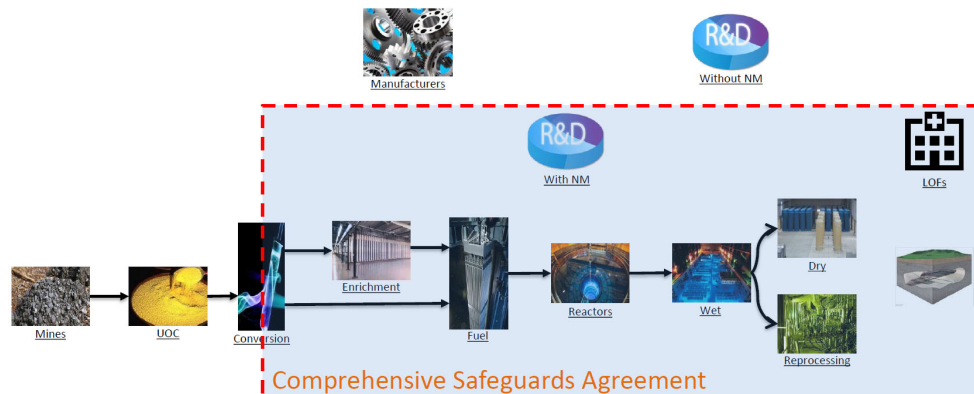


Art. 2a. (iii) / (i) / (iv) / (v) / (ix) / (x), Art 2b.(i)(ii)

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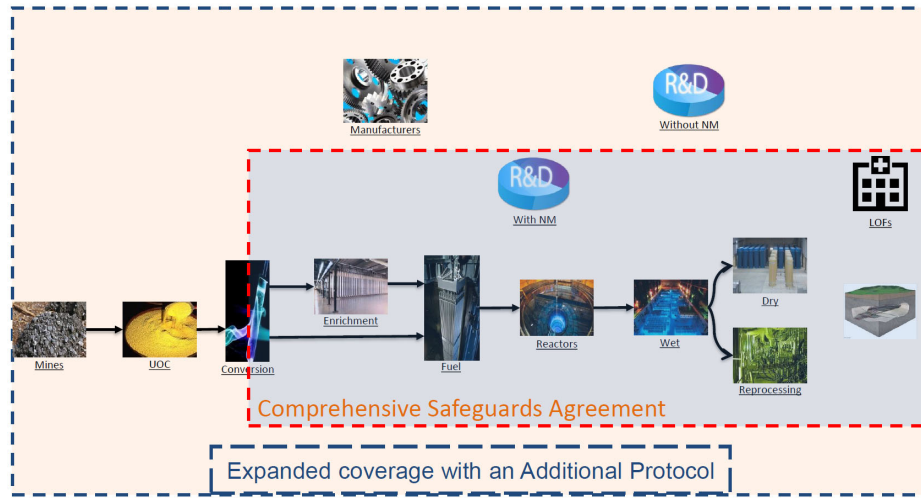
SAFEGUARDING THE NUCLEAR FUEL CYCLE (CSA)



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SAFEGUARDING THE NUCLEAR FUEL CYCLE (CSA + AP)



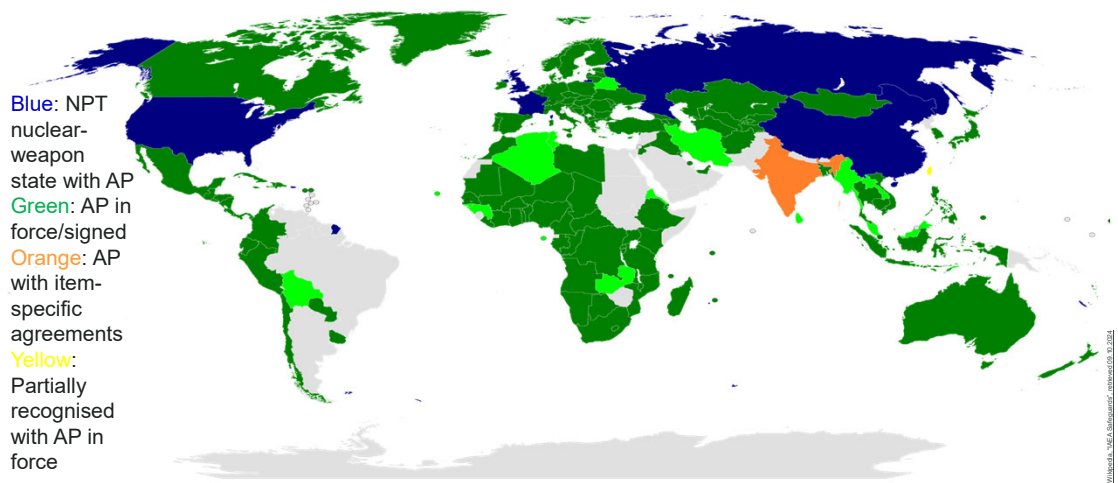
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MAP OF ADDITIONAL PROTOCOL COUNTRIES



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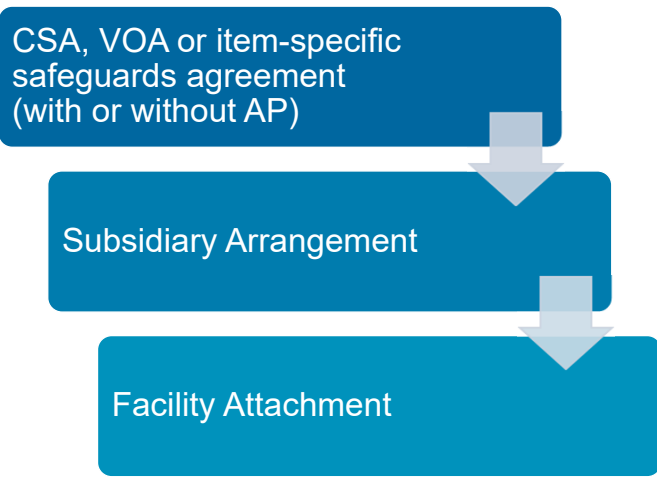


SUBSIDIARY ARRANGEMENTS AND FACILITY ATTACHMENTS

- **Safeguards agreements** provide only the basic obligations for the states and the IAEA
- **Subsidiary Arrangements** specify the administrative and technical procedures how to implement the safeguards agreement (e.g. how to report).
- Subsidiary Arrangements are again supplemented by **facility attachments**, which give detailed information on each facility, e.g.:
 - general information on the facility
 - how and what records are kept
 - how and what data can be collected by the IAEA



HIERARCHY OF SAFEGUARDS AGREEMENTS

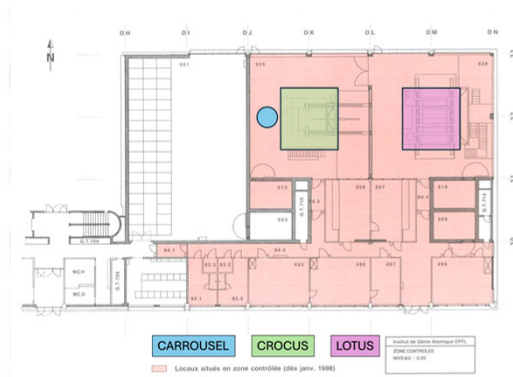


| SAFEGUARDS AGREEMENT BETWEEN SWITZERLAND AND THE THE INTERNATIONAL ATOMIC ENERGY AGENCY FOR THE APPLICATION OF SAFEGUARDS (INF/CRC/264) | | |
|---|--------------------------------------|---|
| Subsidiary Arrangements | | |
| Facility Attachment No. 9 | | Crocus Research Reactor |
| Facility Code: CH-I | | MBA Code: CH-I |
| Total number of pages: 17 | | Page 1 of 17 pages |
| Code | General Part Reference Article | Agreement Reference Article |
| I. | 43(a) | Identification of the facility |
| 1.1 | | Facility identification code: CH-I Name, owner and operator Name: CROCUS - Réacteur Nucléaire Expérimental De Puissance Nulle destiné principalement à l'enseignement à l'Ecole Polytechnique Fédérale de Lausanne. Owner: EPFL - Ecole Polytechnique Fédérale de Lausanne. Operator: LRS - Laboratoire de Physique des Réacteurs et de Comportement des Systèmes |
| 1.2 | | Geographical location: Ecole Polytechnique Fédérale de Lausanne Laboratoire de Physique des Réacteurs et de Comportement des Systèmes |
| 1.3 | | Postal address: Ecole Polytechnique Fédérale de Lausanne, Faculté des sciences de base, Institut de Physique des l'Energie et des Particules, CH-1015 Lausanne, Switzerland |
| 1.4 | | Description Critical assembly, very low power (100 W), 0.9 % - 1.8 % enriched UO ₂ and U-metal fuel, light water moderated, cooled and reflected. Purpose: Educational purposes and research on reactor physics. Output: The nuclear material inventory is approx. 0.63 effective kilograms (ekg). There is no spent fuel in the facility. Fuel are located in the fuel core and at the fresh fuel storage. |
| 1.5 | | Maps and plans Attached herewith: Figure 1: Site location Figure 2: Facility location Figure 3: Facility layout |



CROCUS FACILITY ATTACHMENT (CSA)

| | | |
|-------|-------|--|
| 3. | | Safeguards measures |
| 3.1 | 29 | Accountancy |
| 3.1.1 | 46(b) | Material balance areas and their identification codes. The facility CHI- constitutes one material balance area, MBA CH-1. |

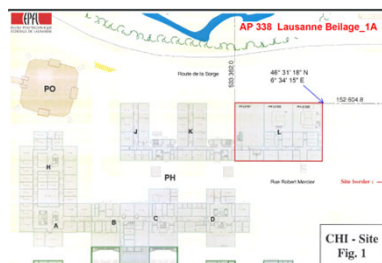


| Code | Grand Part Référence (Code) | Agencement Référence (Article) |
|-------|-----------------------------|---|
| 3.1.2 | 46(b), 98K, 98S | Strategic points which are key measurement points (KMPs) (for these specifications see Code 4): a) For determination of nuclear material flow: KMP 1 - Receipt and de-emption of nuclear material, accidental gain; KMP 2 - Shipment, nuclear loss, exemption of nuclear material, accidental loss; (b) KMP A - Fresh fuel storage; KMP B - Core; KMP C - Spent fuel storage; KMP D - Other locations of nuclear material at the facility. |
| 3.1.3 | 46(c) | Physical inventory taking. Normally once per calendar year at approximately annual intervals. The period between consecutive PITs shall not exceed 14 months. Procedures: (a) Item counting and identification; (b) Preparation in advance of PIT of an itemized inventory list of all the nuclear materials in the MBA. |
| 3.2 | 29 | Containment and surveillance |
| 3.2.1 | 46(f), 98S | Strategic points for application of containment and surveillance measures: None |
| 3.2.2 | 75(d), (e) | Installed Agency instruments and devices: Seals on shipping casks with spent fuel. |
| 3.3 | 74 | Other strategic points Other strategic points at the facility, e.g., for environmental sampling activities, will be determined and agreed upon, taking into consideration the specific character of the facility in relation to the application of Agency safeguards measures. |
| 3.4 | 11, 35(a) | Specific provisions and criteria for termination of safeguards on nuclear material None |
| 3.5 | 36 | Specific provisions and criteria for exemption of safeguards on nuclear material None |

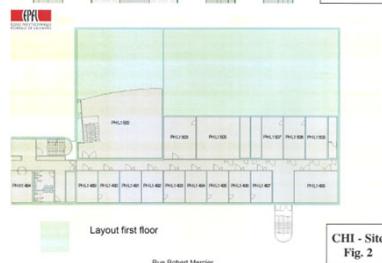
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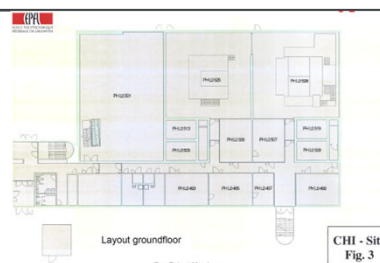
CROCUS SITE DECLARATION (AP)



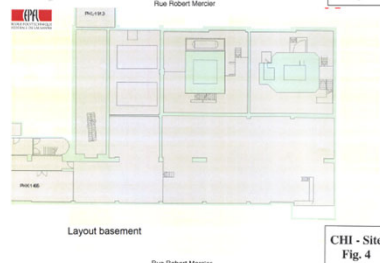
CHI - Site Fig. 1



CHI - Site Fig. 2



CHI - Site Fig. 3



CHI - Site Fig. 4

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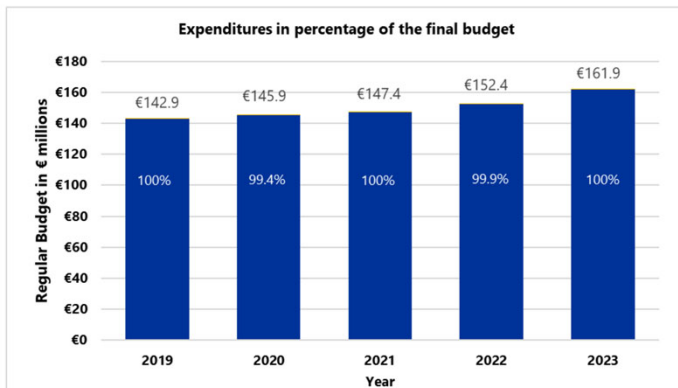


SAFEGUARDS CONCLUSIONS BY THE IAEA

- Depending on the type of safeguards agreement the IAEA draws different safeguards conclusions once a year:
 - "...that **all** nuclear material remained in peaceful activities" (CSA + AP)
 - "...that **declared** nuclear material remained in peaceful activities" (only CSA)
 - "...that nuclear material, facilities or other items to **which safeguards had been applied** remained in peaceful activities" (item-specific agreements)
 - "...that nuclear material in **selected facilities to which safeguards had been applied** remained in peaceful activities or had been withdrawn from safeguards as provided for in the agreements" (VOA)
- If discrepancies are found the IAEA tries to resolve them together with the state, but if the IAEA finds that a state is not complying with its safeguards obligation it can report this to the United Nations Security Council



IAEA 2023 SAFEGUARDS REPORT



Verifying the peaceful use of nuclear material
IAEA Safeguards in 2023

190 States with comprehensive safeguards agreements in force (CSA + AP)
142 States had additional protocols in force

21 States with comprehensive safeguards agreements and optional additional protocols in force
79 States with comprehensive safeguards agreements and optional additional protocols

235 939 kilograms of nuclear material
1367 licensed facilities and locations under IAEA safeguards

€162 million regular budget (4.6% above 2022)
848 staff from 105 countries

Conducted 3136 in-field verifications
Spent 14 302 days in the field for verification
Verified 26 000 seals required to protect material, facility critical equipment or IAEA safeguards equipment at nuclear facilities

Collected 600 environmental samples
Collected 565 nuclear material samples
Acquired 1768 commercial satellite images

Monitored 165 facilities via remote data transmission
Utilized 1056 non-destructive assay systems for the measurement of nuclear material
Maintained 1376 surveillance cameras at nuclear facilities

The IAEA concluded that for ...

- 74 States** all nuclear material remained in peaceful activities
- 107 States** declared nuclear material remained in peaceful activities
- 3 States** nuclear material, facilities or other items to which safeguards had been applied remained in peaceful activities
- 5 States** nuclear material in selected facilities to which safeguards had been applied remained in peaceful activities

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Take aways

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TAKE AWAYS (1)

- Materials and equipment for peaceful and military nuclear uses are very similar, **but**
 - Uranium enriched to 3-5% or $\geq 90\%$ in U-235
 - Pu in MOX fuel or weapons-grade
- Nuclear Non-Proliferation Treaty (1970)
 - 3 pillars (disarmament, peaceful uses and safeguards)
 - All non-nuclear weapon states accept IAEA safeguards
- Nuclear material definition (IAEA statute Art. XX):
 - “Source material”: natural uranium, uranium depleted in U-235, thorium
 - “Special fissionable material”: Pu-239, U-233, uranium enriched in U-235 or U-233

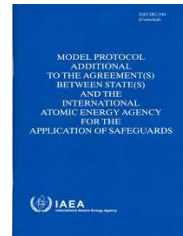
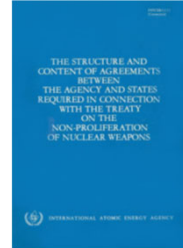


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TAKE AWAYS (2)

- “Traditional” (CSA) safeguards rely on declarations and the verification of nuclear activities
- The Additional Protocol (INFCIRC/540) can be added
 - It gives the IAEA more tools to detect undeclared activities, e.g. Complementary Access and more declared information
- Agreements are complemented by Subsidiary Arrangements and Facility Attachments
- The IAEA draws safeguards conclusions and investigates potential cases of non-compliance further before eventually reporting it to the United Nations Security Council



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NEXT TIME

- Nuclear landscape in Switzerland
- Legal basis in Switzerland
- Safeguards measures by the IAEA
- Statistics and IAEA conclusions for Switzerland
- Export controls

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THANK YOU FOR YOUR ATTENTION

Questions?

 Schweizerische Eidgenossenschaft
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