Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Bundesamt für Energie BFE
Office fédéral de l'énergie OFEN
Ufficio federale dell'energia UFE
Uffizi federal d'energia UFE

Source: www.zwilag.ch

Non-Proliferation Introduction to Safeguards

Uwe Georg, Swiss Federal Office of Energy (SFOE)

Non-Proliferation in Switzerland, EPFL, 13 December 2024

CONTENT

Practical application of safeguards in Switzerland

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

Export Control

Introduction

Short refresher

SHORT REFRESHER

- Material/equipment is similar for peaceful and military nuclear uses.
  - Entire fuel cycle needs to be safeguarded.
- Treaty on the Non-Proliferation of Nuclear Weapons
  - 3 pillars (disarmament, peaceful uses and safeguards).
  - 5 official nuclear weapon states.
  - All non-nuclear weapon states accept IAEA safeguards.
- Comprehensive Safeguards Agreement (CSA) is the standard agreement.
  - Can be complemented by the Additional Protocol (AP), which gives the IAEA a more complete picture of nuclear activities in a country.
  - Every CSA is supplemented by a Subsidiary Arrangement and the respective facility attachments.

NUCLEAR MATERIAL (IAEA STATUTE ART. XX)

Source material

- **Uranium** containing the mixture of isotopes occurring in nature,
- **Uranium depleted** in the isotope 235,
- **Thorium**,
- any of the foregoing in the form of metal, alloy, chemical compound or concentrate, and…

Special fissionable material

- **Plutonium-239**,
- **Uranium-233**,
- **Uranium enriched** with the isotopes 235 or 233,
- any material containing one or more of the foregoing, and…

- Dependent on the processing stage
- No lower limit
- Independent on intended use

Legal basis of safeguards in Switzerland

SWITZERLAND AND THE NPT

- Signature of the NPT 1 July 1968.
- Ratification of the NPT 9 March 1977.
- CSA and AP in force.
- Switzerland renounces possession and manufacturing of nuclear weapons.
- Free access to the peaceful use of nuclear energy.
- All nuclear material will be under international safeguards (IAEA Safeguards).

- Swiss regulator also implements safeguards for Liechtenstein (bilateral agreement).

INTERNATIONAL NON-PROLIFERATION TREATIES AND SWITZERLAND

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

CH ratified 9 March 1977

§Comprehensive Safeguards Agreement (CSA)

CH ratified 6 September 1978

&Additional Protocol to the CSA (AP)

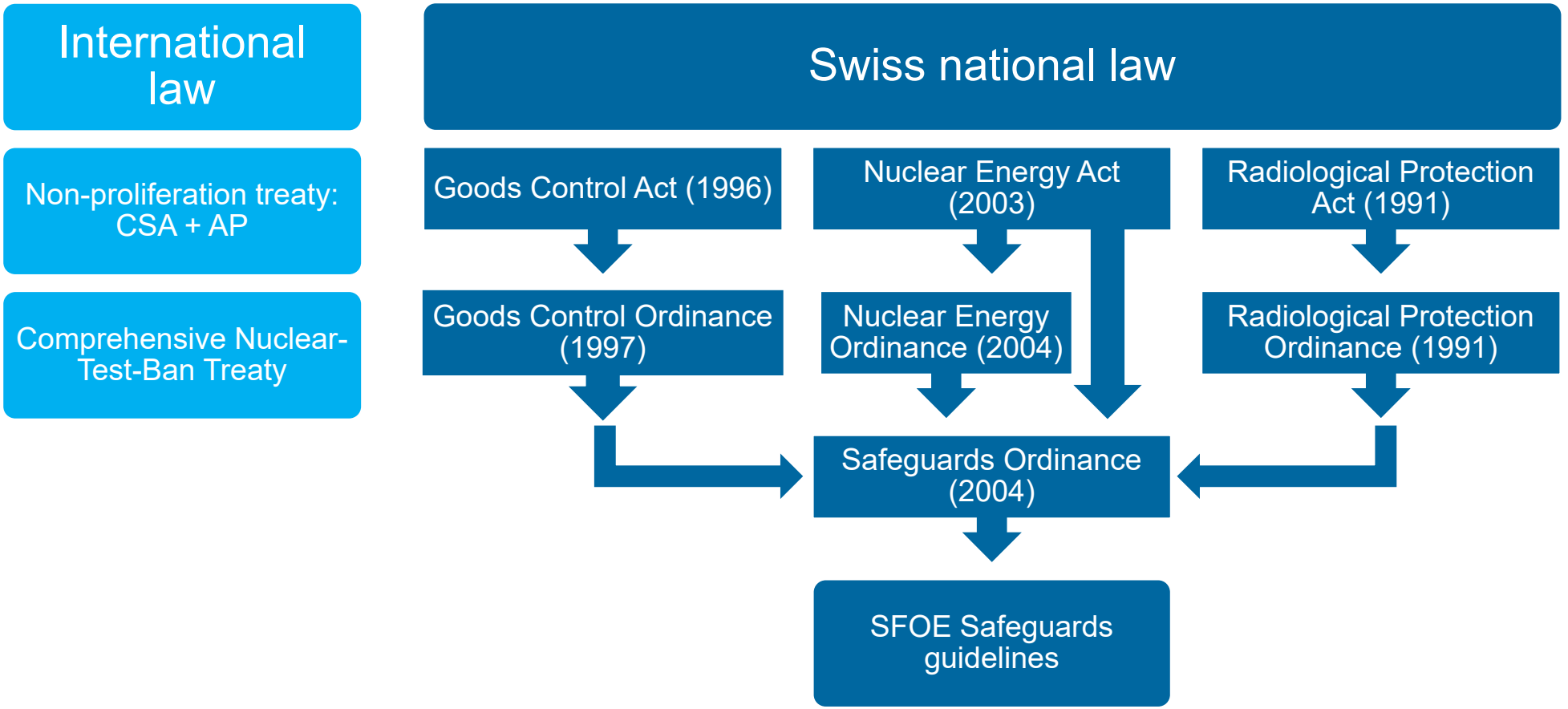
CH ratified 1 February 2005

CH = Confederatio Helvetica = Switzerland

§ compulsory for non-nuclear-weapon states

& not compulsory but almost a “standard”

SWISS LAW ON NUCLEAR NON-PROLIFERATION



SFOE SAFEGUARDS GUIDELINES

- Based on the Safeguards Ordinance SFOE (BFE) has developed Safeguards Guidelines for users of nuclear materials
  - BFE-SG01: Reporting obligations for materials in locations outside facilities
  - BFE-SG02: Safeguards measures in facilities
  - BFE-SG03: Reporting obligations for nuclear materials in facilities
  - (*BFE-SG06: Nuclear material accountancy for materials abroad)

*no safeguards obligation

FACILITY AND LOCATIONS OUTSIDE FACILITIES

- IAEA Glossary 5.24 and 5.25

5.24. Facility — "a reactor, a critical facility, a conversion plant, a fabrication plant, a reprocessing plant, an isotope separation plant or a separate storage installation; or any location where nuclear material in amounts greater than one effective kilogram is customarily used" [153, para. 106], [540, Article 18.j]. Under [66], two kinds of facility are defined (in paras 78 and 81, respectively).

5.25. Location outside facilities (LOF) — "any installation or location, which is not a facility, where nuclear material is customarily used in amounts of one effective kilogram or less" [540, Article 18.j]. This term also applies under para. 49 of [153], where LOF is described as a location containing "nuclear material customarily used outside facilities". The corresponding term under para. 66 of [66] is 'other locations', which is used in INFCIRC/66-type safeguards agreements to refer to installations where nuclear material outside of principal nuclear facilities is held, e.g. source material stored elsewhere than in a sealed storage facility.

Nuclear landscape in Switzerland

FACILITIES/LOCATIONS UNDER IAEA SAFEGUARDS

NPP	ID	Type	Operation
Beznau I	KKB I	PWR	1969
Beznau II	KKB II	PWR	1971
Mühleberg[#]	KKM	BWR	1971-2019
Gösgen	KKG	PWR	1979
Leibstadt	KKL	BWR	1984

Interim Storage Facilities	Operation
ZWILAG	2001
ZWIBEZ	2007
AERA (radioactive waste from medicine, Industry and research)	1992

CERN
Storage of disused nuclear materials

[#] in decommissioning

Geological repository in planning

Research Reactors	Status
Crocus (EPFL Lausanne)	in operation (1983)
Proteus (PSI)	in decommissioning
Saphir (PSI)	decommissioned
Diorit (PSI)	decommissioned
AGN 211 (Univ. Geneva)	decommissioned
AGN 201 (Univ. Basel)	decommissioned

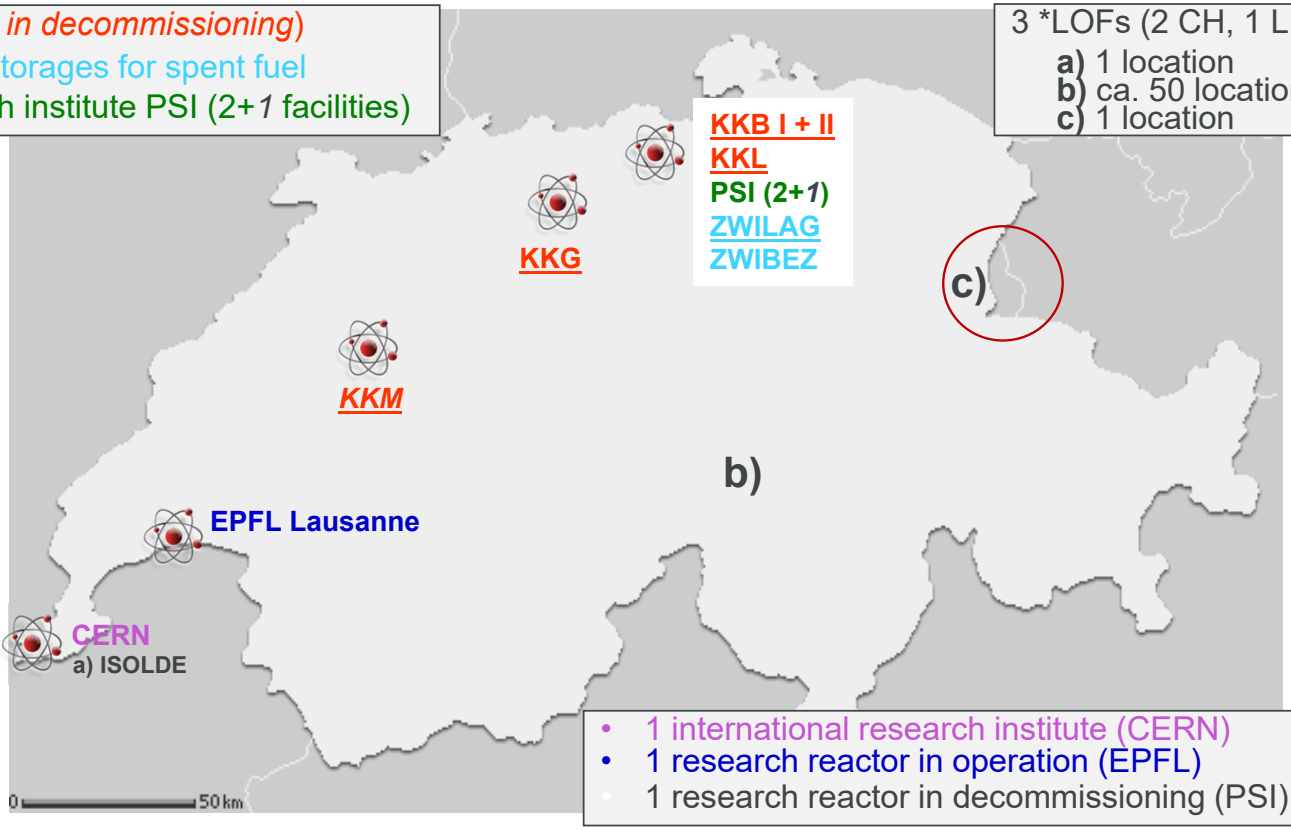
Paul Scherrer Institut (PSI)	Operation
Hot Labor (with hot cells)	1965

LOFs (Locations outside Facilities)
ISOLDE (CERN)
CHX- (ca. 50 locations in Switzerland)
LNX- (1 location in Liechtenstein)

Not anymore under IAEA safeguards

FACILITIES/LOCATIONS UNDER IAEA SAFEGUARDS

- 4 NPPs (*1 in decommissioning*)
- 2 Interim storages for spent fuel
- 1 Research institute PSI (2+*1* facilities)



3 *LOFs (2 CH, 1 LI)
a) 1 location
b) ca. 50 locations
c) 1 location

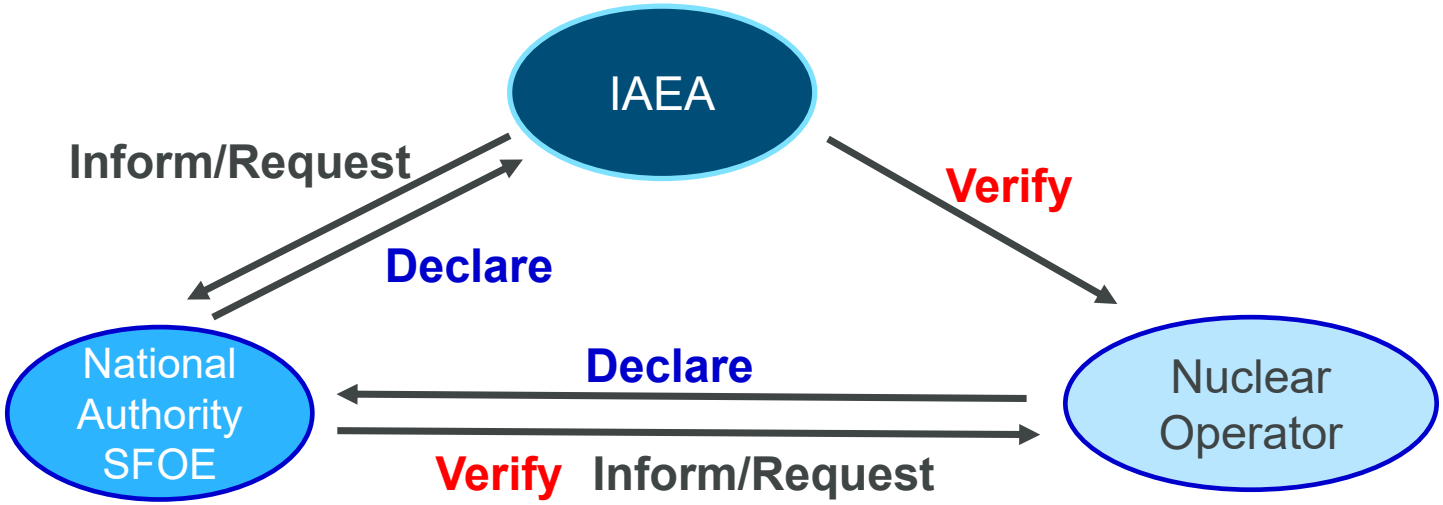
- 1 international research institute (CERN)
- 1 research reactor in operation (EPFL)
- 1 research reactor in decommissioning (PSI)

* LOF = Location Outside Facilities

Underlined: Facilities with IAEA remote monitoring

IAEA safeguards activities in Switzerland

SAFEGUARDS PARTIES



- SFOE is always present during IAEA inspections.
- Operator is not in direct contact with the IAEA.

REPORTING AND NOTIFICATIONS

- Facility operators are obliged to report to SFOE and to cooperate with SFOE and IAEA
- **Design Information Questionnaire (DIQ)**
- **Nuclear Material Accounting (NMA)**
  - ICR: Inventory Change Report
  - PIL: Physical Inventory Listing
  - MBR: Material Balance Report
- **Notifications**
  - Advance notifications (transport of NM)
  - Unscheduled activities and findings
- **Declarations according to the AP**

INVENTORY CHANGE REPORT (ICR) FORM

COUNTRY : CH — REPORTING PERIOD: FROM : 010217 TO : 010326

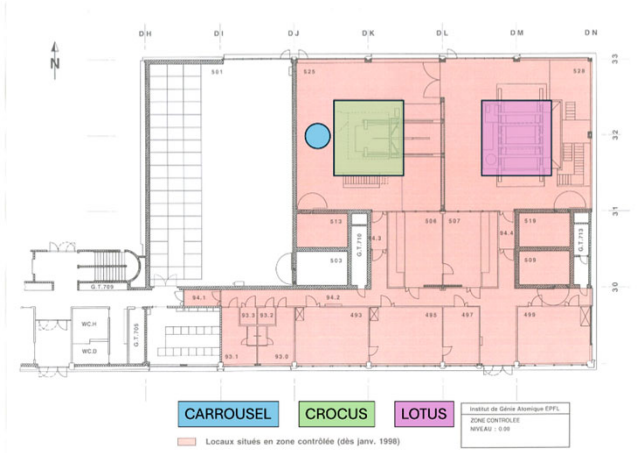
FACILITY : CHL- — REPORT No. : 0743 — Nr. of En

MATERIAL BALANCE AREA : CH-L — PAGES No. 1 of 1 PAGES — SIGNATURE :

ENTRY NO.	CONTINUATION	DATE OF INVENTORY CHANGE	MBA/COUNTRY FROM	MBA/COUNTRY TO	TYPE OF INVENTORY CHANGE	KMP CODE	NAME OR NUMBER OF BATCH	NUMBER OF ITEM IN BATCH	MATERIAL DESCRIPTION	ACCOUNTANCY DATA ELEMENT	ACCOUNTANCY DATA WEIGHT OF ELEMENT	ACCOUNTANCY DATA UNIT kg/g	ACCOUNTANCY DATA WEIGHT OF FISSILE ISOTOPES (URANIUN ONLY) (g)	ISOTOPE CODE	MEASUR. BASIS
1	3	4	10	14	18	20	21	29	33	37	38	46	48	56	72
01		010326	CH-L	F	SF	2	KLG118	1	BQ3G	U	169660	G	701	G	M
02	C							0		P	1595	G			

DESIGN INFORMATION QUESTIONNAIRE (DIQ)

- Provides general information about a facility, e.g. location, normal capacity
- Establishes Material Balance Areas (MBA) and Key Measurement Points (KMP)



NUCLEAR MATERIAL FLOW

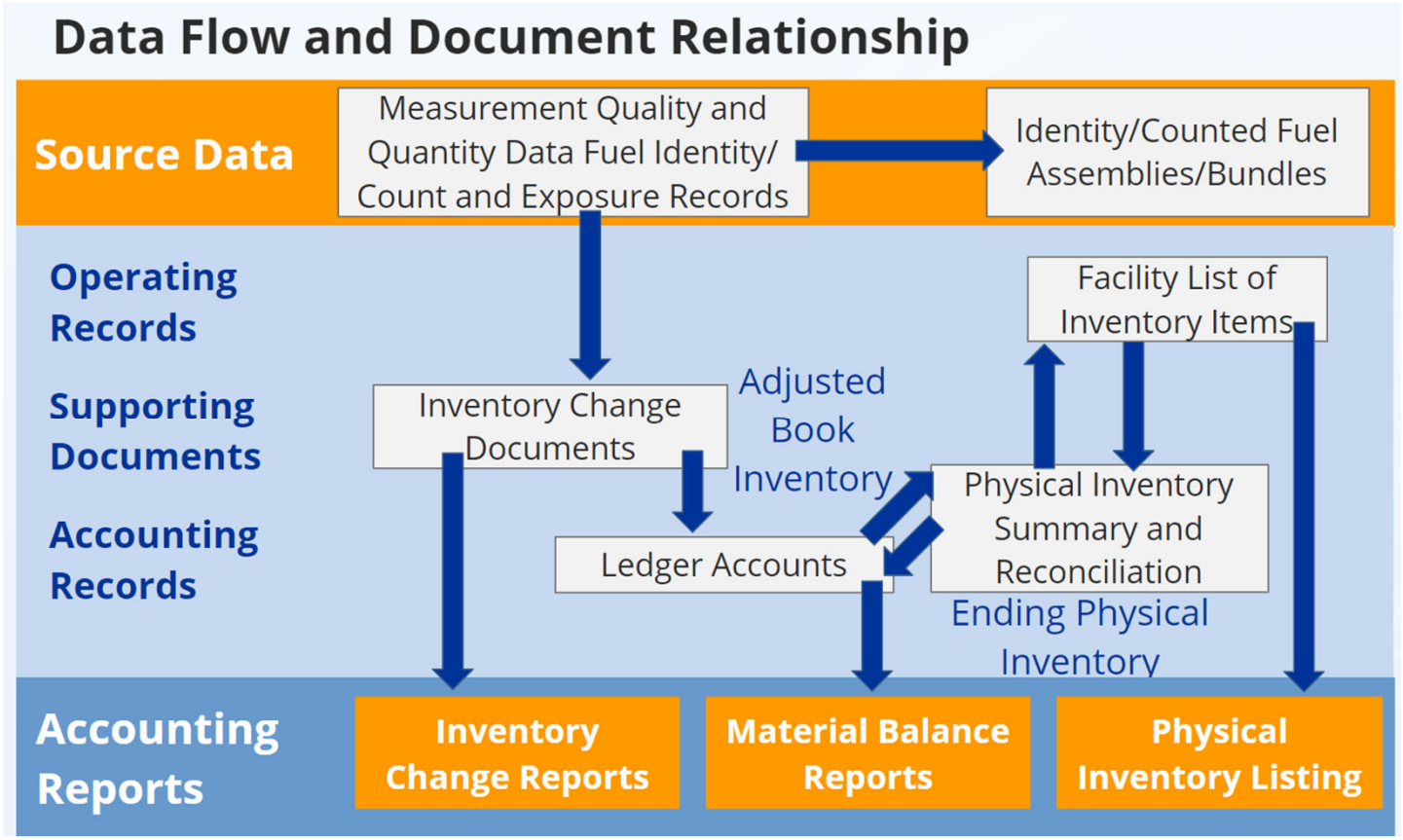
33.	SCHEMATIC FLOWSHEET FOR NUCLEAR MATERIAL (identifying measurement points, accountability areas, inventory locations, etc.)	DIAGRAM(S) ATTACHED UNDER REF. Nos. Flow KMPs: 1: Receipt and de-exemption of nuclear material, accidental gain 2: Shipment, nuclear loss and production, exemption of nuclear material, accidental loss 3: Rebatching Inventory KMPs: A: Fuel storage B: CROCUS reactor C: Spent fuel pond (not applicable) D: Other locations inside the facility
34.	INVENTORY STATE QUANTITY RANGE, NUMBER OF ITEMS, AND APPROXIMATE URANIUM ENRICHMENT AND PLUTONIUM CONTENT FOR (under normal operating conditions):	
	i) Fresh Fuel Storage	About 700 kg U metal with 0.947% enrichment (156 items) About 15 kg U oxyde with 1.8% enrichment (14 tems) About 3 kg Th About 10 kg natural U About 10 g depleted U

ALL FACILITIES

GENERAL INFORMATION

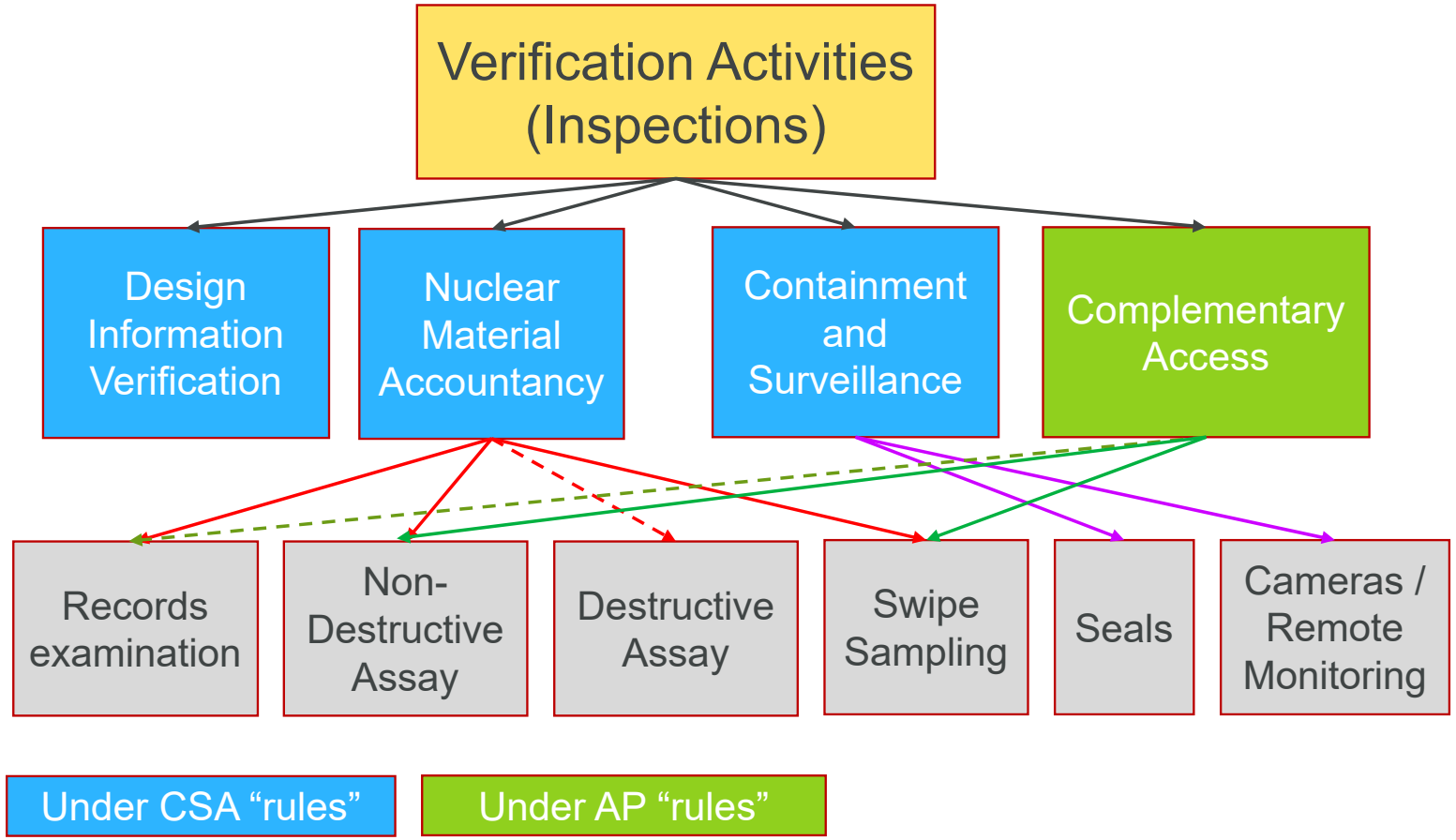
1.	NAME OF THE FACILIYTY (incl. usual abbreviation)	CROCUS is a zero-power research reactor at École Polytechnique Fédérale de Lausanne in Switzerland.
2.	LOCATION AND POSTAL ADDRESS	Ecole Polytechnique Fédérale de Lausanne (EPFL) Faculté des sciences de base (SB) Institut de physique de l'énergie et des particules (IPEP) Laboratoire de physique des réacteurs et de comportement des systèmes (LRS) CH-1015 Lausanne Switzerland
3.	OWNER (legally responsible)	EPFL: Ecole Polytechnique Fédérale de Lausanne
4.	OPERATOR (legally responsible)	LRS: Laboratoire de physique des réacteurs et de comportement des systèmes
5.	DESCRIPTION (main features only)	Zero-power light water reactor (100 W)
6.	PURPOSE	Teaching and study of reactor behaviour
7.	STATUS (planned; under construction; in operation)	In operation
8.	CONSTRUCTION SCHEDULE DATES (if not in operation)	Start of Construction — Commissioning — Operation
9.	NORMAL OPERATING MODE (days only, two shift, three shift; number of days/annum, etc.)	Approximately 60 days/annum
10.	FACILITY LAYOUT (structural containment, fences, access, nuclear material storage areas, laboratories, waste disposal areas, routes followed by nuclear material, experimental and test areas, etc.)	DRAWING(S) ATTACHED UNDER REF. Nos. The LRS includes a facility (LOTUS) dedicated to material irradiation with gamma and neutron sources See attachment 3
11.	SITE LAYOUT (site plan showing in sufficient detail; location, premises and perimeter of facility, other buildings, roads, railways, rivers, etc.)	DRAWING(S) AND/OR MAPS ATTACHED UNDER REF. Nos. See attachments 1 and 2
12.	NAMES AND/OR TITLES AND ADDRESS OF RESPONSIBLE OFFICERS (for nuclear material accountancy and control and contact with the Agency. If possible attach organization charts showing position of officers)	Dr. Pavel Frajtag EPFL SB-IPEP-LRS PH-Ecublens CH-1015 Lausanne Switzerland

NUCLEAR MATERIAL ACCOUNTING (NMA)



- NMA is the basis for nuclear safeguards to detect diversion of materials
- IAEA inspectors check the book inventories against what is actually there
- Nuclear material inventories are reported and tracked for every facility and all MBAs/KMPs

IAEA ACTIVITIES IN THE FIELD



CONDUCTING INSPECTIONS

Typical Procedure

- Work safety and radioprotection briefing (IAEA inspector)
- Pre job briefing
- Contamination check (Equipment and staff)
- Entering controlled area

- Inspection activities, e.g.
  - Verifying the inventory
  - Installing/Exchanging/Verifying seals
  - Measure enrichment levels
  - Verifying facility design information

- Contamination check (Equipment and staff)
- Leaving controlled area
- Post job briefing, open issues etc.

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Eidgenössisches Departement für Umwelt, Verkehr, Energie und Kommunikation UVEK
Bundesamt für Energie BFE
Sektion Safeguards

INTERN

Inspektionsprotokoll

Anlage:	CHI- (EPFL)	**Datum:** DD.MM.YYYY
Inspektionstyp:	PIV & DIV (mit IAEA)	**Beginn:** hh.mm **Ende:** hh.mm
MBP:	DD.MM.YYYY – DD.MM.YYYY	

Teilnehmer

BFE:	
IAEA:	
Anlage:	

Inspektionsstandard

Verif.-Ausrüst.:	☐ ICVD	☐ HM-5	☐ FDET	☐ SFAT	**Siegel:**	☐ Metall	☐ Passive
☒ ^{3}He (Krit.-Test)	☐ XCVD	☐ MMCC	☐ IRAT	☐ ES	☐ EOSS	☐ Cobra	☐ Papier
Bemerkungen:							

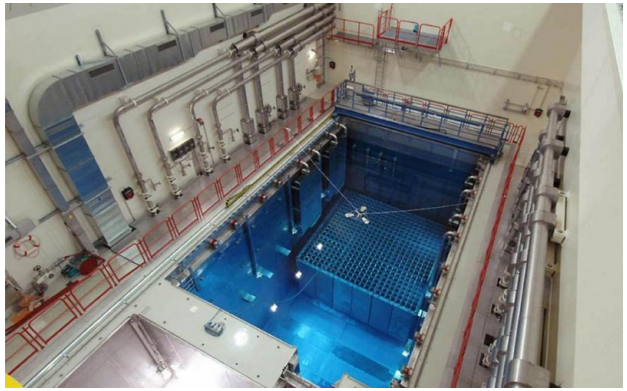
Erledigt	Tätigkeiten	Startzeit (opt)
☐	Pre-Job Briefing: Inspektions-Aktivitäten überprüft und Ablauf vereinbart.	
☐	Dokumente an IAEA überreicht und Buchhaltung geprüft. ☒ GL/SL ☒ PIL ☐ Karten/Pläne ☐ ICR ☒ MBR ☒ Item-List	
☐	Kritikalitätstest mit ^{3}He-Detektor im Kanal durchgeführt.	
☐	Item Counting und Identifikation durchgeführt (vollständig/partiell).	
☐	XX Proben mit HM-5 gemessen (Batches …).	
☐	DIV durchgeführt (…).	
☐	Evtl. Bilder wurden aufgenommen, siehe Ablage «…».	
☐	Debriefing durchgeführt.	
☐		
☐		
☐		

Bemerkung(en)

a)	
b)	
c)	

	Aktion(en)	Verantw.	Frist
1)			
2)			
3)			

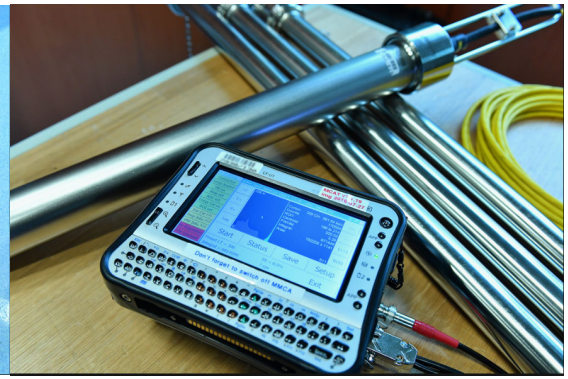
DESIGN INFORMATION VERIFICATION (DIV)



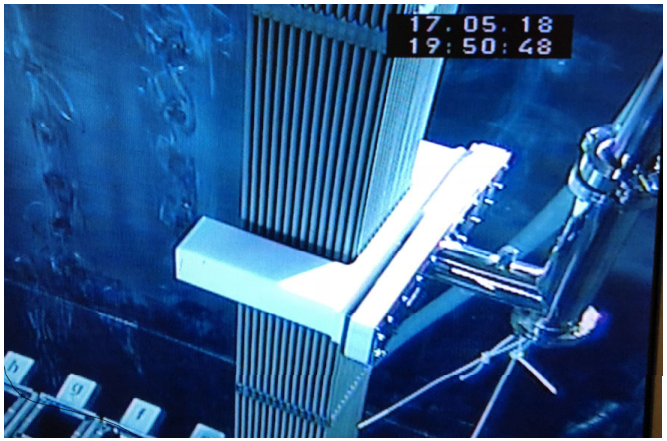
NON-DESTRUCTIVE ASSAY (GAMMA & NEUTRONS)

Hand-held spectrometer

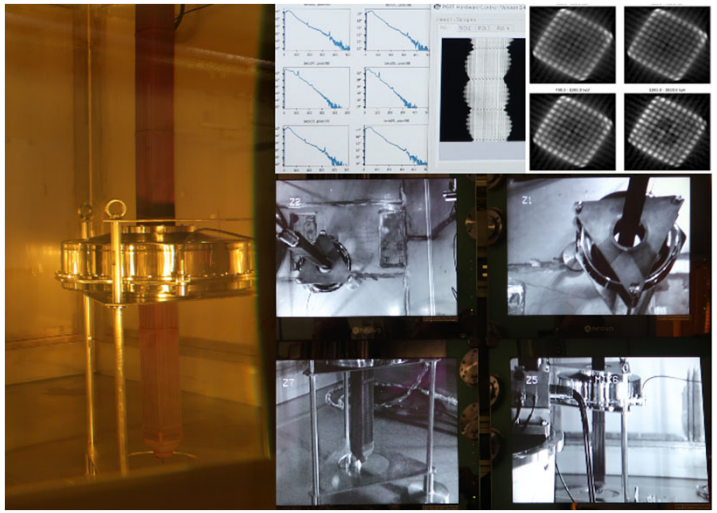
Spent Fuel Attribute Tester (SFAT)



Fork Detector



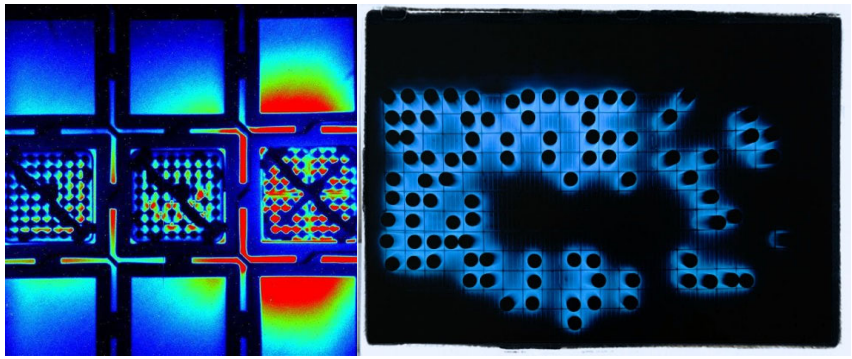
Passive Gamma Emission Tomography (PGET)



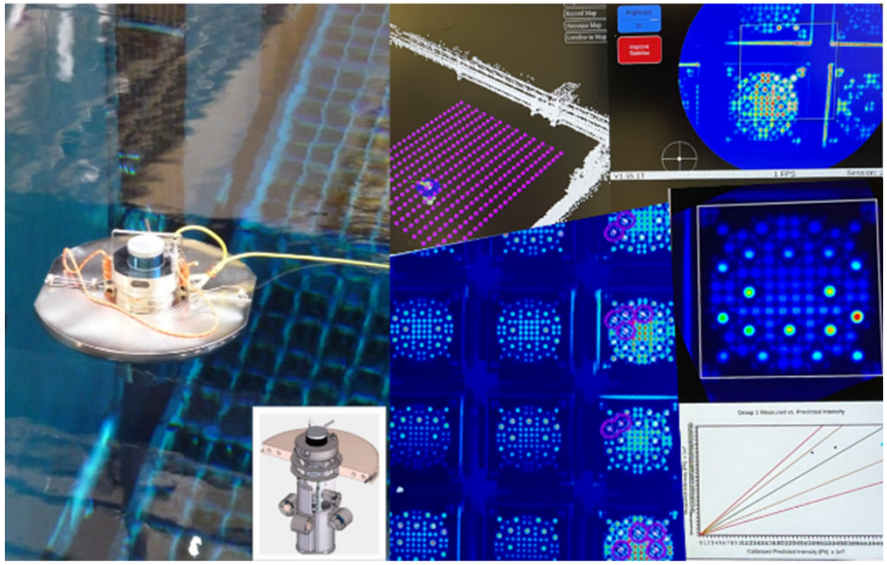
NON-DESTRUCTIVE ASSAY (CERENKOV RADIATION FROM SPENT FUEL)

ICVD – Improved Cerenkov Viewing Device

DCVD – Digital Cerenkov Viewing Device



RCVD – Robotized Cerenkov Viewing Device



SWIPE SAMPLES

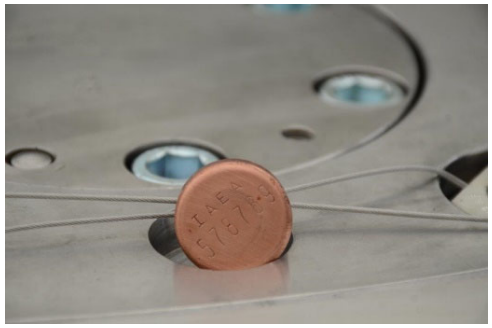
Collected to verify the absence of nuclear material or to confirm state declarations on nuclear activities.

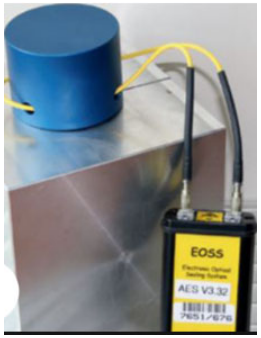
Sample kit for environmental sampling.
(Photo: IAEA Department of Safeguards)

Samples analysed at the IAEA Seibersdorf NML and/or at labs of the Network of Analytical Laboratories (NWAL).

CONTAINMENT AND SURVEILLANCE C/S (SEALS)

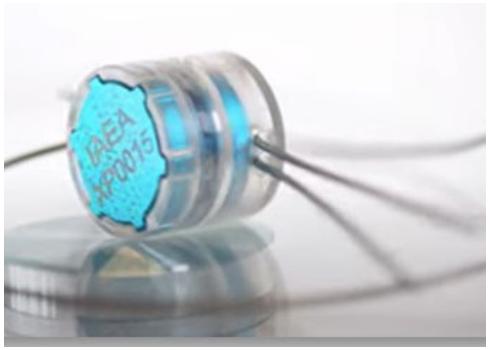
«Old» **cap seal** (single use)



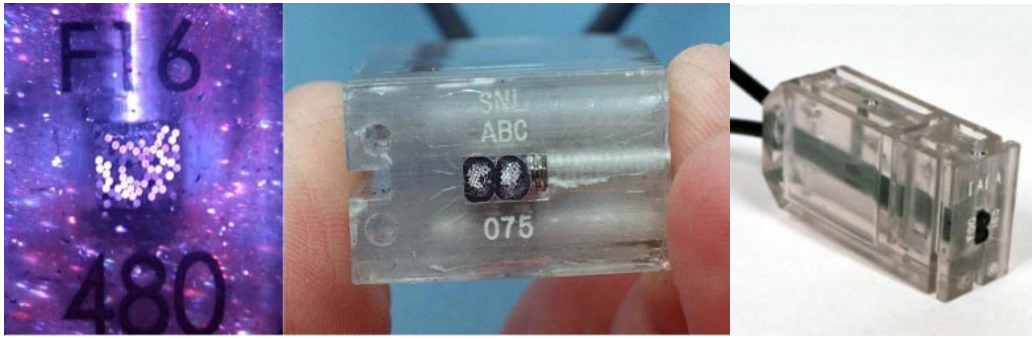


EOSS Electronic Optical Seal System (multi use) for regular access and long duration (in situ verifiable)

«New» **cap seal: Field Verifiable Passive Seal** (in situ verifiable)



COBRA seal (singe use) Fibre optic loop with verification tools (in situ verifiable)



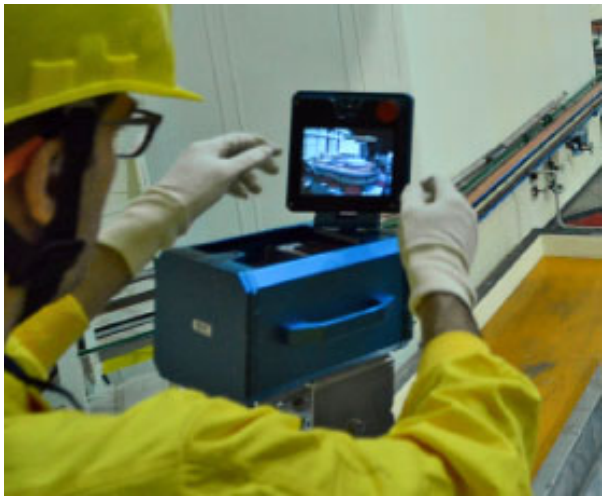
CONTAINMENT AND SURVEILLANCE C/S (CAMERAS / REMOTE MONITORING)

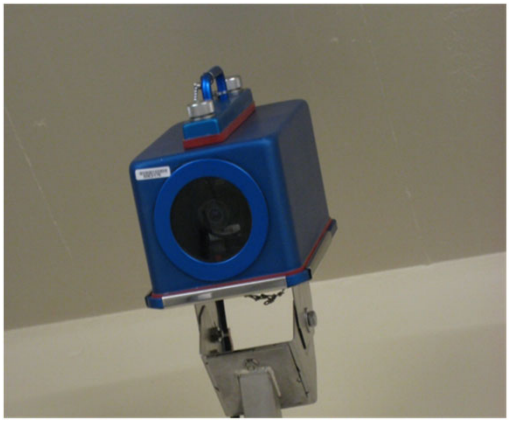
NGSS (Next Generation Surveillance System) for long term installation.

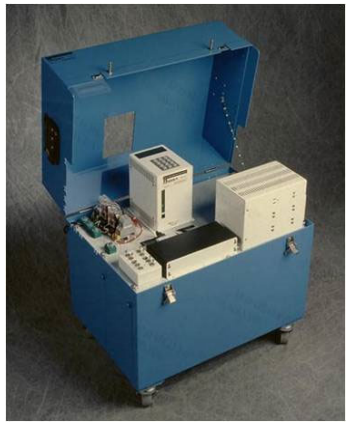
Remote monitoring is performed from the IAEA headquarters.

SFOE has to notify the IAEA about activities in the camera field:

- In advance by RMS monthly reports for planned activities.
- Event based by notification in case of impairment.



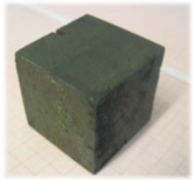




Safeguards in location outside facilities

LOFS – MATERIALS UNDER SAFEGUARDS

- Uranium and thorium in metallic form and in alloys;
- Uranium ores and thorium ores, including other uranium/thorium-containing minerals, from which uranium or thorium is or is to be extracted for industrial use;
- Shielding made of uranium (e.g. in systems for gamma radiography);
- Chemicals containing uranium and/or thorium (e.g. uranyl acetate, uranyl oxalt, uranyl nitrate, uranium oxide, thorium oxide, thorium nitrate hydrate, etc.);
- Uranium used as tritium storage;
- Components made of uranium/thorium/plutonium in measuring instruments (e.g. fission chamber);
- Calibration sources with uranium and/or thorium;
- Plutonium in any form.

LOFS – MATERIALS OUTSIDE SAFEGUARDS

- Objects coated with uranium and/or thorium (e.g. optical lenses);
- Objects made of uranium glass (e.g. optical lenses, plates, bowls, etc.);
- Uranium in filters from drinking water treatment plants, as long as the uranium is not extracted;
- Uranium and thorium contained in natural materials (earth, water, plants, etc.);
- Glazes containing uranium (e.g. tiles);
- Thorium alloys provided the thorium was terminated during the manufacture of the alloy (e.g. thorium electrodes and engine components);
- Thorium-containing mantles for gas lamps.




IAEA safeguards conclusions in Switzerland

SOME NUMBERS (2022)

- Material Balance Areas: 12
- Locations Outside Facilities: ~50

- Nuclear Material:
  - Plutonium: ~24 t (mainly in spent fuel)
  - Uranium: ~2250 t
  - Thorium: ~190 kg

- Staff: 6 (5.6 FTE)
- Person days in the field: 98

- IAEA inspections:
  - Regular: 43
  - Non-regular: 62
  - Complementary Access: 1

- Environmental Samples:
  - 7 (2023)
  - 9 (2022)

- Seals: ~130 installed
- Cameras: 22 fixed (+ 8 temporary)

MISSION ACCOMPLISHED

STATE EVALUATION PROCESS BY THE IAEA

Evaluating the fulfilment of States' safeguards commitments

DEPUTY DIRECTOR GENERAL

Holds overall responsibility for the State Evaluation Process, Prioritization, Planning & Approval

SAFEGUARDS OPERATIONS DIVISIONS

DIRECTORS

Hold responsibility for Safeguards implementation in countries in their Division.

SECTION HEADS

SENIOR INSPECTORS

STATE EVALUATION GROUP (SEG)

Established for each State by the Director of the relevant Operations Division, SEGs continously evaluate the fulfilment of the safeguards commitments made by States with the IAEA.

COUNTRY OFFICER

Appointed by the Operations Director to lead the SEG; initiate actions and reports; define the work plan and duties of SEG members; and report progress and issues.

MEMBERS

Collaborate under the leadership of the Country Officer and provide specialized expertise as required.

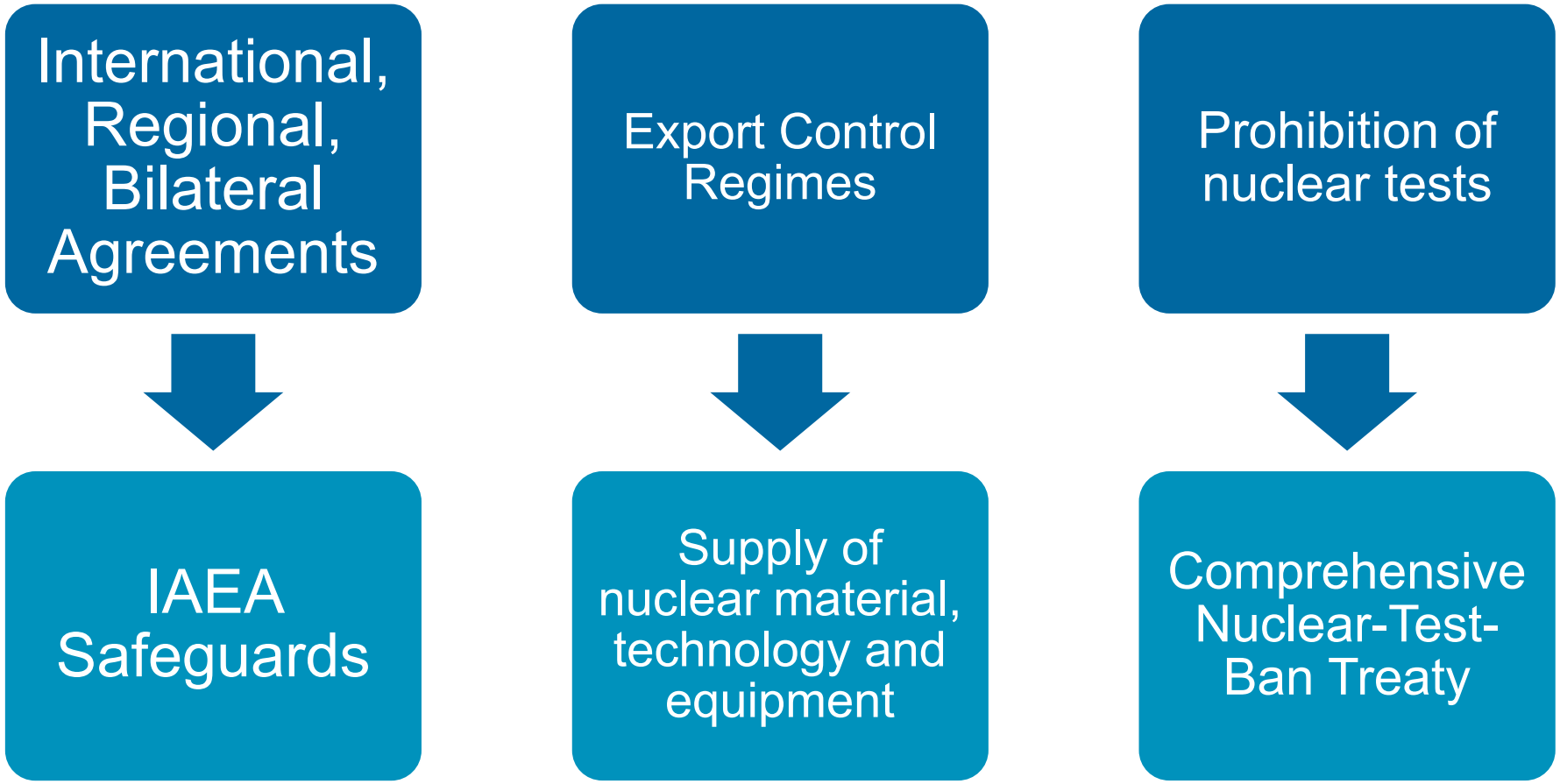
Divisions of Operations (SGOs)	Division of Information Management (SGIM)	Division of Concepts & Planning (SGCP)
~ 2 - 5 members	~ 1 - 2 members	~ 0 - 1 member

Ad hoc members:

Division of Technical & Scientific Services (SGTS), Office of Safeguards Analytical Services (SGAS), and Office of Information & Communication Systems (SGIS).

Export controls in a nutshell

THE NUCLEAR NON-PROLIFERATION REGIME



NPT ART. 3 (2)

…
Each State Party to the Treaty undertakes not to provide:

a. source or special fissionable material, or
b. <u>equipment or material especially designed or prepared "(EDP)"</u> for the processing, use or production of special fissionable material,

to any non-nuclear-weapon State for peaceful purposes, unless the source or special fissionable material shall be subject to the safeguards required by this Article.

…

ZANGGER COMMITTEE (ZC)

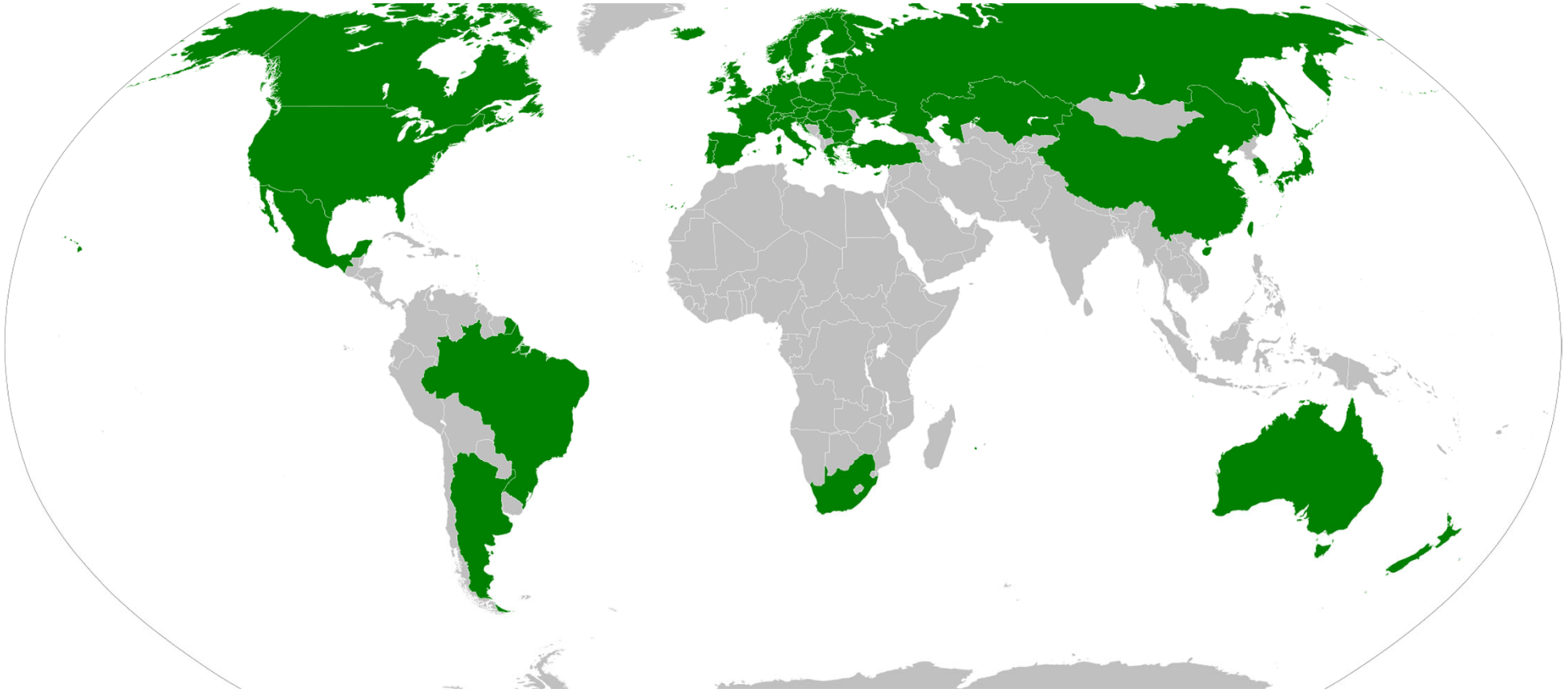
- 1st chairman Claude Zangger (former SFOE deputy director)
- Main purpose to define the EDP on a “trigger list” and guidelines to regulate exports
- Mostly done between 1971 and 1974 but continually updated

NUCLEAR SUPPLIERS GROUP (NSG)

- Formed in 1974 as a reaction to first Indian nuclear explosion
- Took over the ZC trigger list and developed further guidelines
- “Government to Government Assurances” cover both exports and imports
- Since 1992 a second list regulates dual-use goods (less stringent controls)

- Core element is international coordination on rejected export requests to prevent subversion of the export controls

NSG MEMBER STATES

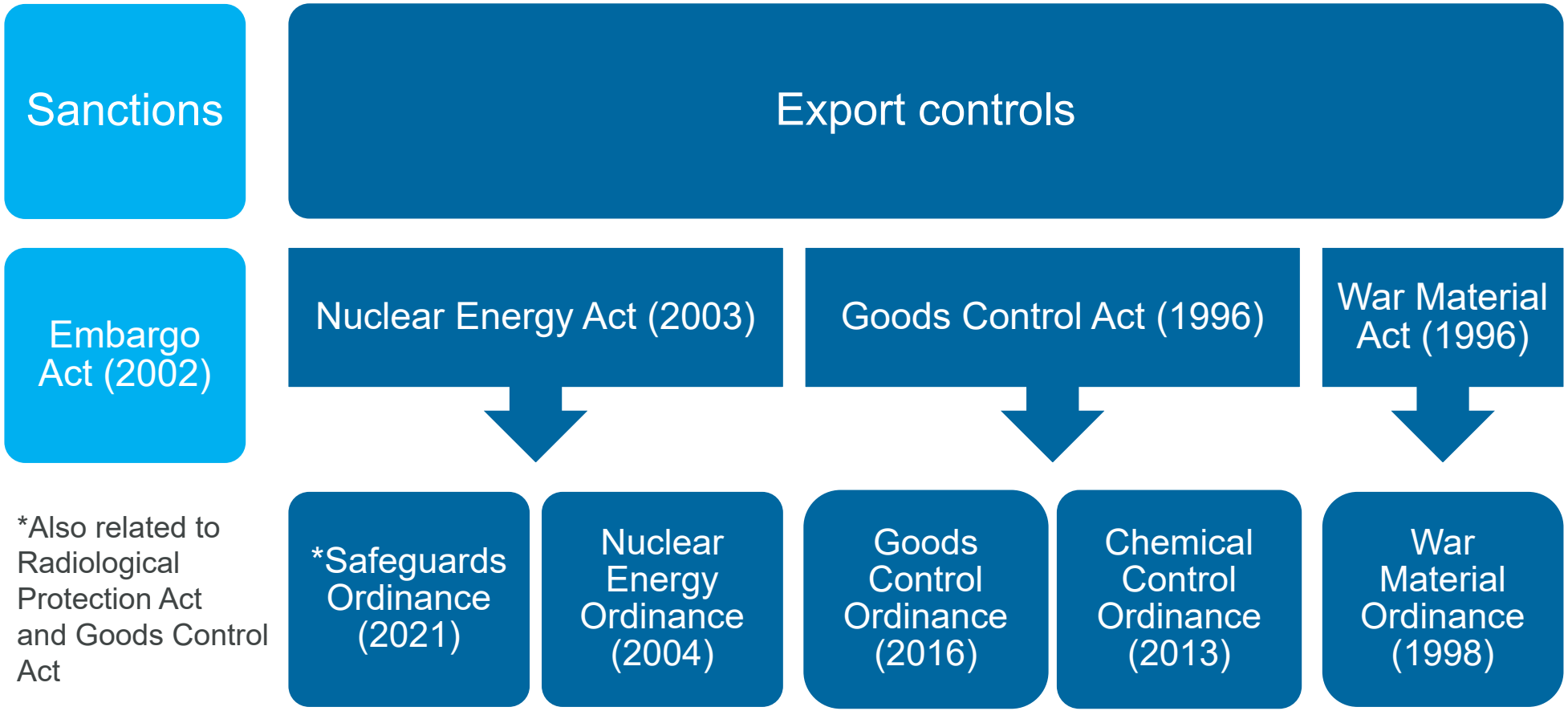


NSG Members - Nuclear Suppliers Group - Wikipedia

EXPORT CONTROLS

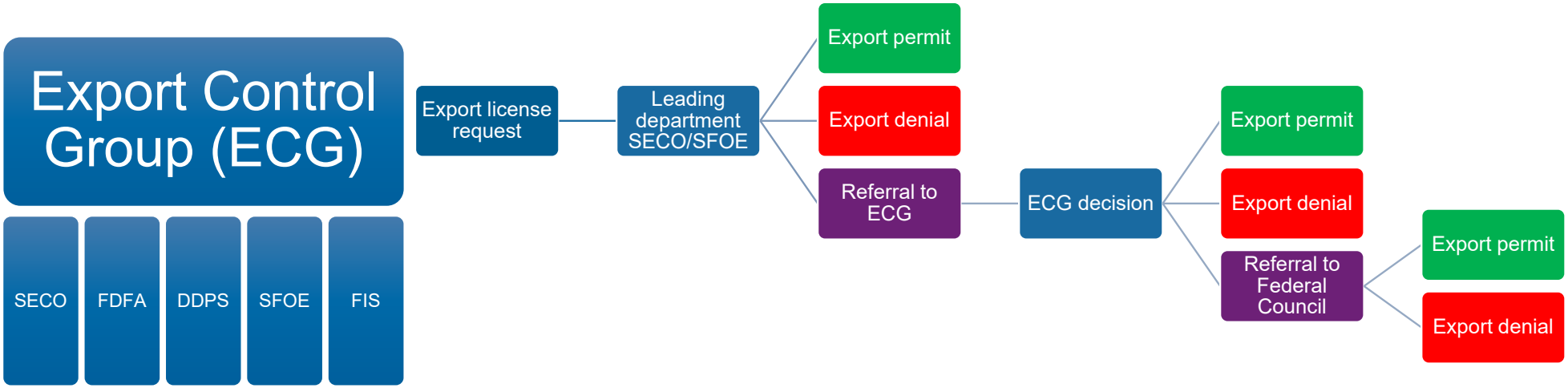
- No general export prohibition, but subject to approval
- Encompasses:
  - Listed goods
  - Technology
  - Software
  - “Catch-all clause” to prevent unlisted exports used in weapons of mass-destruction programmes

SWISS EXPORT CONTROL LAW



SWISS EXPORT CONTROL SYSTEM

- The State Secretariat for Economic Affairs (SECO) is in charge of export controls overall (Goods Control Act)
- SFOE is in charge of nuclear materials (Nuclear Energy Act)
- Complex cases are discussed in the Export Control Group (ECG)
- If ECG cannot agree the matter is refereed to the Federal Council



Non-proliferation – a success story?

IS NON-PROLIFERATION A SUCCESS STORY?

- Non-proliferation efforts have:
  - significantly slowed the spread of nuclear weapons;
  - persuaded some states to give up their nuclear programs;
  - made the spread of peaceful nuclear technologies possible in the first place.

  - not prevented that there are more nuclear weapon states than in the 1960s;
  - not led to nuclear disarmament

International cooperation is essential to keep the non-proliferation regime working

Take aways

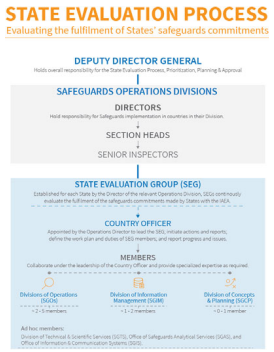
TAKE AWAYS (1)

- International safeguards obligations implemented in Swiss national law
- Reporting obligations by facility operators through the SFOE
  - Design of facilities
  - Nuclear material accountancy
  - Advance notifications
  - AP declarations

- IAEA verifies the declarations e.g. by measuring samples

TAKE AWAYS (2)

- Broader conclusion for Switzerland since 2015
- Export control regimes control transfer of regulated goods including dual-use goods
- Non-proliferation:
  - is based on legal obligations;
  - is verified by technical means;
  - requires international cooperation spanning various fields of expertise;
  - made the spread of nuclear technology possible.



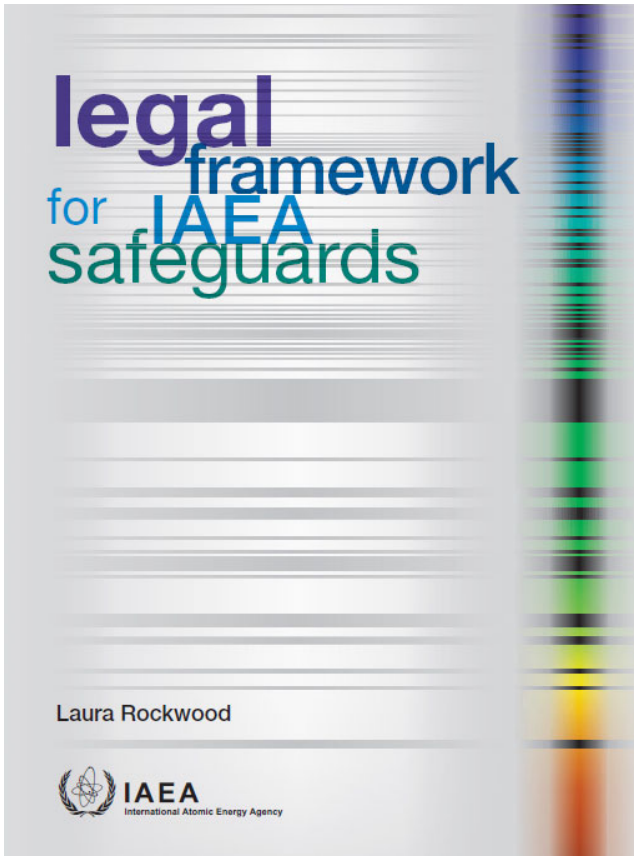
THANK YOU FOR YOUR ATTENTION

Questions?

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

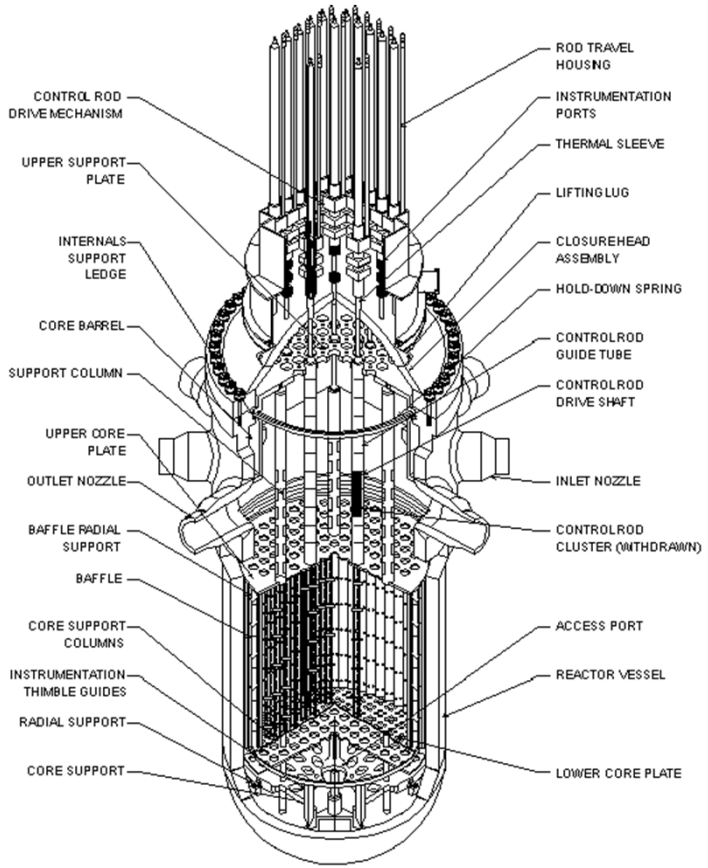
Swiss Federal Office of Energy SFOE
Uwe Georg
Head of Safeguards
CH-3003 Berne

Phone: +41 58 462 00 78
E-Mail: uwe.georg@bfe.admin.ch



EXPORT LICENSE REQUIRED?

EXPORT LICENSE REQUIRED?



EXPORT LICENSE REQUIRED?

EXPORT LICENSE REQUIRED?

EXPORT LICENSE REQUIRED?

EXPORT LICENSE REQUIRED?

AFRL-RH-WP-TR-2017-XXXX

Be consistent with the font size (i.e., Main Title-16 pt/Bold, all caps; Subtitle- 14 pt/bold)

MAIN TITLE

Subtitle *(if applicable)*

Author(s) First name/Last name

Contractor Company Name *(if applicable)*

Author(s) First name/Last name

Subcontractor Company Name *(if applicable)*

Month/Year

Final Report

THIS IS A SMALL BUSINESS INNOVATION RESEARCH (SBIR) PHASE I REPORT

DISTRIBUTION STATEMENT B: Distribution authorized to U.S. Government agencies only; Proprietary Information (SBIR Data Rights), Critical Technology and Export Controlled; Month 2XXX. Other requests for this document shall be referred to 711 HPW/RHC, Wright-Patterson AFB, OH 45433.

WARNING: This document contains technical data whose export is restricted by the Arms Export Control Act (Title 22, U.S.C., Sec. 2751, et seq.) or the Export Administration Act of 1979, as amended, Title 50 U.S.C., App. 2401, et seq. Violations of these export laws are subject to severed criminal penalties. Disseminate in accordance with the provisions of DoD Directive 5230.25. (Include this statement with any reproduced portions).

DESTRUCTION NOTICE – Destroy by any method that will prevent disclosure of contents or reconstruction of the document.

See additional restrictions described on inside pages.

AIR FORCE RESEARCH LABORATORY
711TH HUMAN PERFORMANCE WING
AIRMAN SYSTEMS DIRECTORATE
WRIGHT-PATTERSON AIR FORCE BASE, OH 45433
AIR FORCE MATERIEL COMMAND
UNITED STATES AIR FORCE

Figure 1. Sample of a Cover Sheet

EXPORT LICENSE REQUIRED?