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Supplement of

International safeguards for the final disposal of spent nuclear fuel – why, what and how

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INTERNATIONAL SAFEGUARDS FOR THE FINAL DISPOSAL OF SPENT NUCLEAR FUEL – WHY, WHAT AND HOW

11.11.2021 I

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Institute of Energy and Climate Research, IEK-6: Nuclear Waste Management

SESSION 4A EN

Activities in international research programs and collaborations

safe ND

Interdisciplinary research symposium on the safety of nuclear disposal practices

JÜLICH Forschungszentrum

Member of the Helmholtz Association

NUCLEAR SAFEGUARDS

To deter the spread of nuclear weapons by the early detection of the misuse of nuclear material or technology


SANTA FE NEW MEXICAN

Los Alamos Secret Disclosed by Truman

ATOMIC BOMBS DROP ON JAPAN

After the **first nuclear bomb was dropped on Hiroshima on 6 August 1945,** US-President Harry Truman unveiled the top-secret **Manhattan Project**.

Atoms for Peace Speech
US-President Dwight D. Eisenhower, UN General Assembly, 8 December 1953

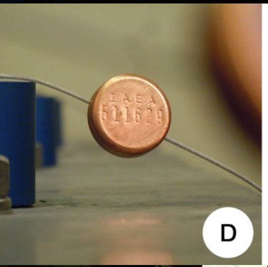
Treaty on the Non-Proliferation of Nuclear Weapons (NPT), 1970

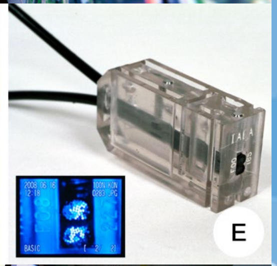
- Non-proliferation (Art. I & II), **Safeguards** (Art. III)
- Peaceful use of nuclear energy (Art. IV & V)
- Disarmament (Art. VI)

IAEA
International Atomic Energy Agency

Generic safeguards objectives

- To detect any diversion of declared nuclear material at declared facilities or locations outside facilities where nuclear material is customarily used (LOFs)
- To detect any undeclared production or processing of nuclear material at declared facilities or LOFs
- To detect any undeclared nuclear material or activities in the state as a whole





IAEA Safeguards in 2020

Verifying the peaceful use of nuclear material

184 States with safeguards agreements in force

of which

136 States had additional protocols in force

31 States with comprehensive safeguards agreements and original small quantities protocols

63 States with comprehensive safeguards agreements and amended small quantities protocols

221 432 significant quantities of nuclear material

1 321 nuclear facilities and locations outside facilities

145 million regular budget
+27 million extra budgetary

875 staff
from 95 countries

Conducted
2 856 in-field verifications
12 767 days in the field
2 362 days under quarantine in country

Verified
23 600 seals applied to nuclear material, facility critical equipment or IAEA's safeguards equipment at nuclear facilities

Collected
460 environmental samples
489 nuclear material samples

Acquired
1 264 commercial satellite images

Remotely monitored
142 facilities

Utilized
1 038 non-destructive assay systems for the measurement of nuclear material

Maintained
1 530 surveillance cameras at nuclear facilities

We concluded that for ...

72 States
all nuclear material remained in peaceful activities

103 States
declared nuclear material remained in peaceful activities

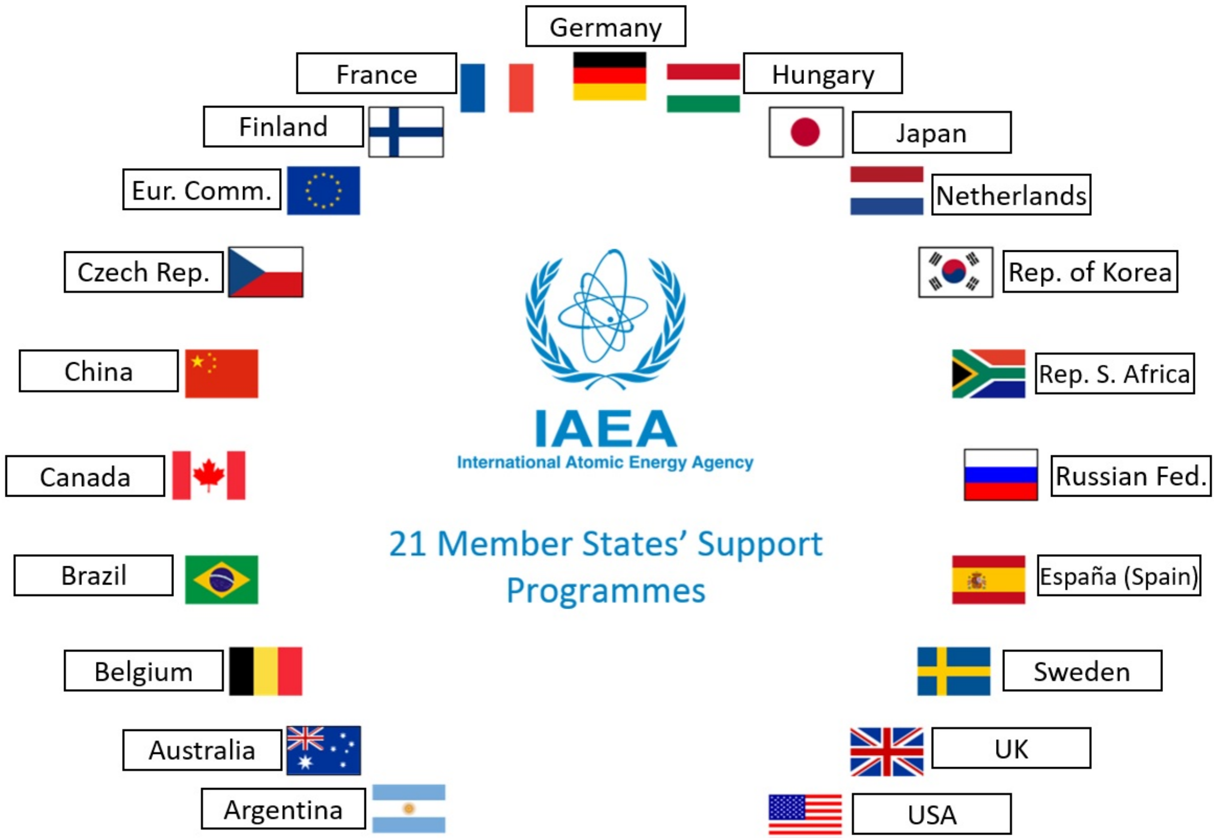
3 States
nuclear material, facilities or other items to which safeguards had been applied remained in peaceful activities

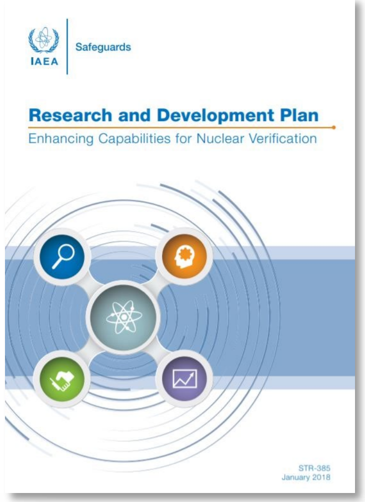
5 States
nuclear material in selected facilities to which safeguards had been applied remained in peaceful activities

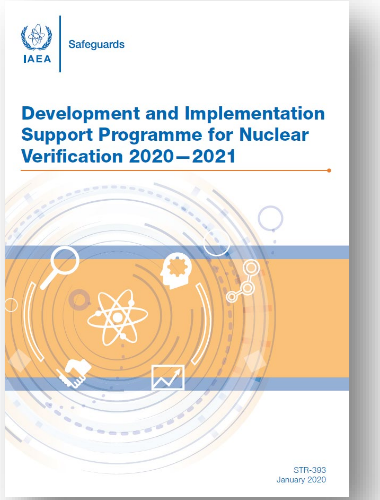
IAEA
International Atomic Energy Agency

INTERNATIONAL COLLABORATION IN SAFEGUARDS

Member State Support Programmes in IAEA Safeguards







INTERNATIONAL COLLABORATION IN SAFEGUARDS

Safeguarding final disposal of spent nuclear fuel - Overview

- 1988: IAEA Advisory Group on Safeguards related to Final Disposal
- 1991: IAEA Consultants' Meeting on Safeguards for Final Disposal
- 1994-1998 IAEA SAGOR Working Group
- 1999-2006 IAEA Group of Experts (SAGOR II)
- 2006-2017: IAEA ASTOR Working Group
- 2018-2019: Consolidation of ASTOR and SAGOR tasks
- 2020: ESARDA Working Group on Final Disposal

SAGOR : Safeguards for Geological Repositories
ASTOR: Application of Safeguards to Geological Repositories
ESARDA: European Safeguards Research and Development Association

SAGOR (1994-1998) & SAGOR II (1999-2006)

Safeguards for Geological Repositories: Reports and activities

SAGOR

STR-312 (1998): Safeguards for the Final Disposal of Spent Fuel in Geological Repositories

SAGOR II

STR-324 (2000): The Use of Geophysical Techniques for Safeguarding Geological Repositories

STR-338 (2003): Interface Issues and Interaction Between Safeguards and Radioactive Waste Management in the Context of Geological Repositories

ASTOR (2006-2017)

Application of Safeguards to Geological Repositories: Reports and activities

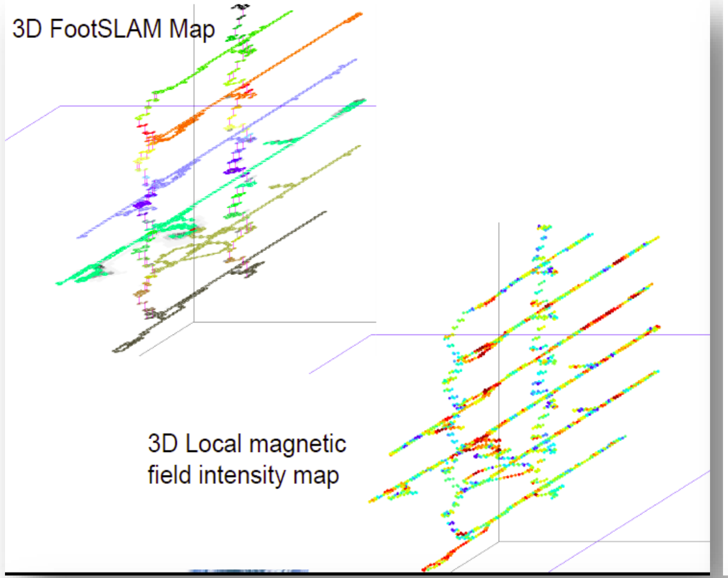
ASTOR

STR-384 (2017): Technologies Potentially Useful for Safeguarding Geological Repositories

Technology principle and brief description	Technologies
• Technology readiness level • Technology limitations • Estimated costs • Sustainability, standardization, supply chain • Ease of use / operator skill / infrastructure needs • Data validation / authentication • Expected 'Alarm' rates	• Design Information Verification (DIV) • Non-destructive analysis (NDA) verification • Containment and surveillance (C/S) measures and canister ID • Satellite imagery • Geophysical techniques (i.a. seismic detection, directional radar technology) • Long-term management of safeguards-related data

DESIGN INFORMATION VERIFICATION (DIV)

Detection of undeclared constructions



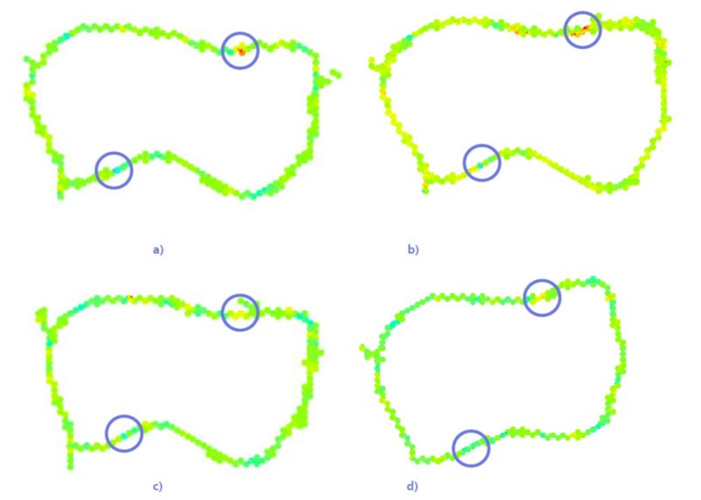


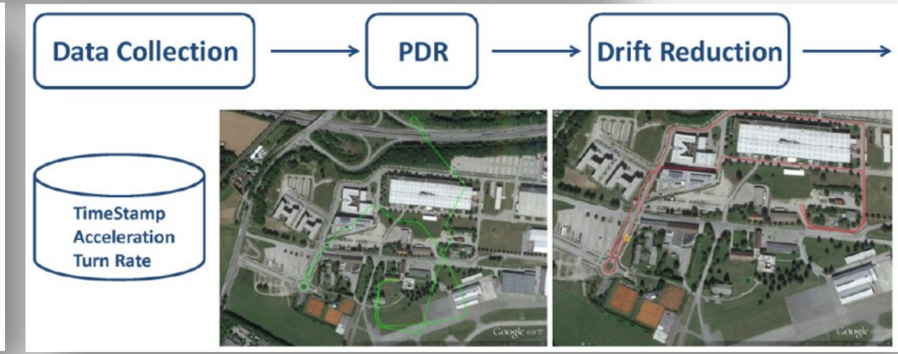
Figure 2: A two layer hierarchical magnetic field map composed of regular hexagonal grids for walk 1-4 (Figure 2 a-d). Distinctive magnetic field characteristics are encircled. The color encodes the sample mean magnetic field intensities of the maximum likelihood particle at the end of the walk, where red encodes higher intensity.

Mounted on the foot

MEM
(from

MEMS Mti Xsens
(www.xsesn.com)

Figure 1: Left: Five DLR employees within the active graphite mine in Kropfmühl close to Passau wearing special clothes and helms; Right: Special waterproof fixation of the sensors at the rubber boots.



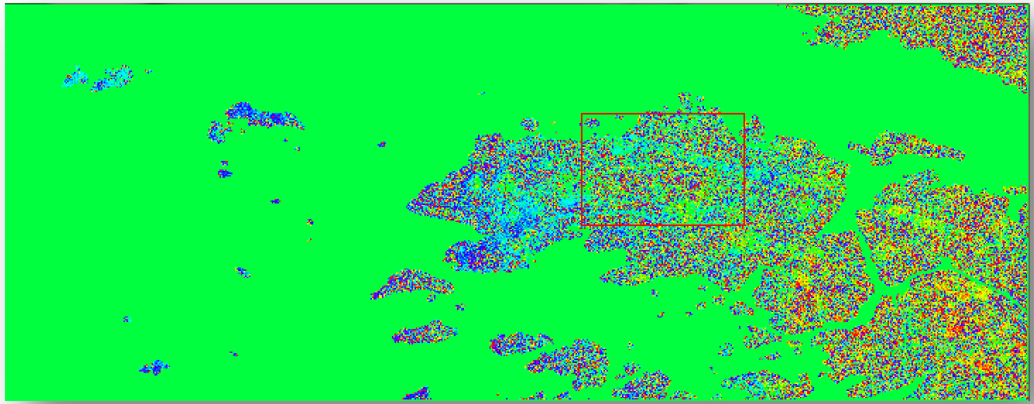
Simultaneous location and mapping (SLAM) (GER-DLR)

S. Kaiser, E. Munoz Diaz, P. Robertson (2016): **Study on the Feasibility of FootSLAM for Use During Safeguards Verification Activities.** JOPAG/03.16-PRG-423

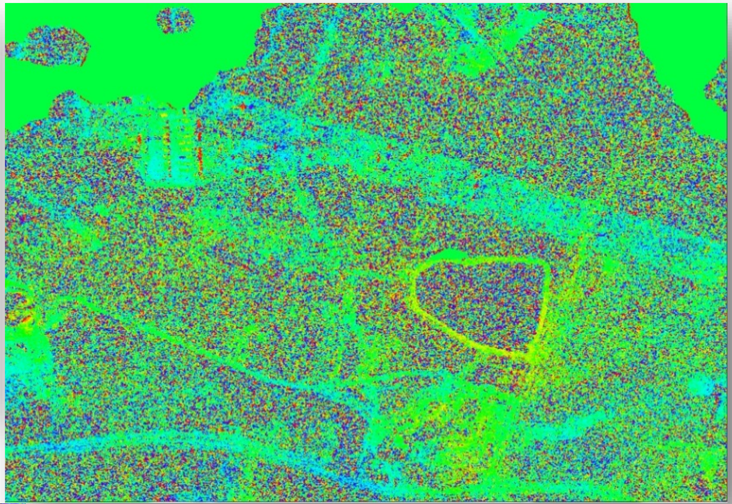
S. Kaiser, E. Munoz Diaz (2016): **FootSLAM2: Enhancing IAEA's Navigation Algorithm for use in Complementary Access Inspections.** JOPAG/03.16-PRG-424

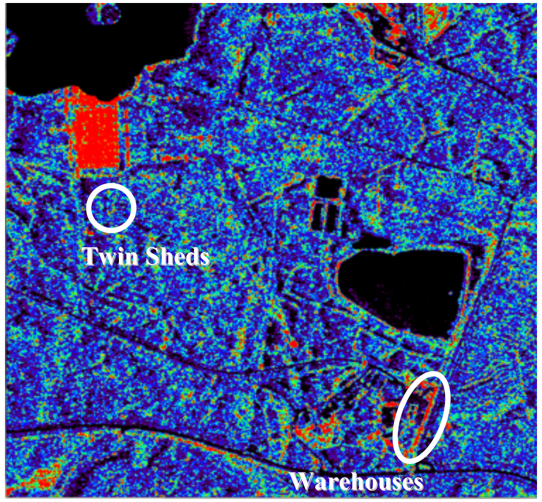
SATELLITE IMAGERY (SI)

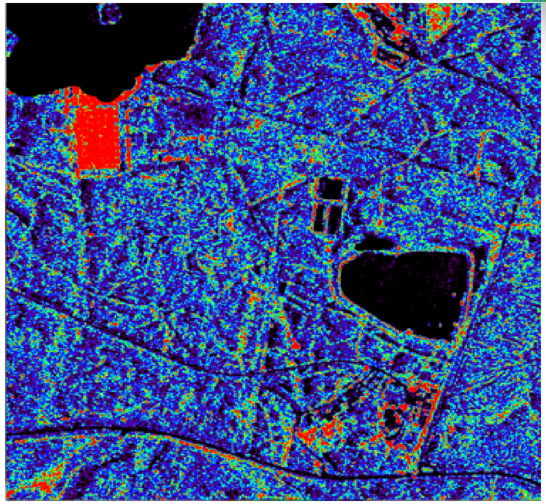
Change detection, deformation analysis



-2π 2π







Application of SAR interferometry and non-coherent change detection techniques (CAN/FIN/GER-Jülich/JPN)

I. Niemeyer, O. Okko, B. Moran, D. Davainius (2018): **Safeguarding Geological Repositories Using Geophysical Monitoring and Satellite Imagery.** Proc. of the INMM Annual Meeting 2018

TerraSAR-X images acquired at May 23 (right) and June 3 (left)

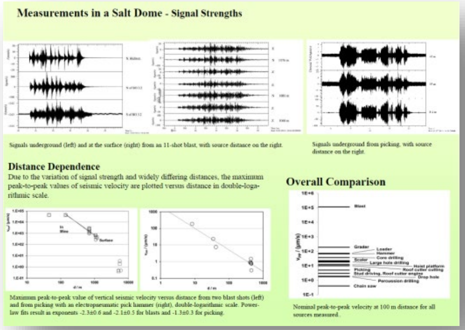
Top: Interferogramm

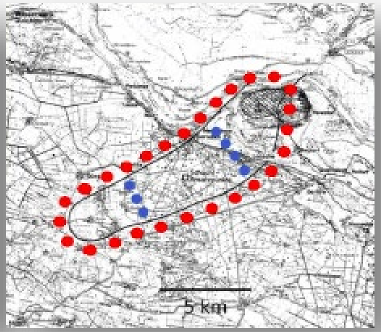
Left: Color-coded backscatter intensity

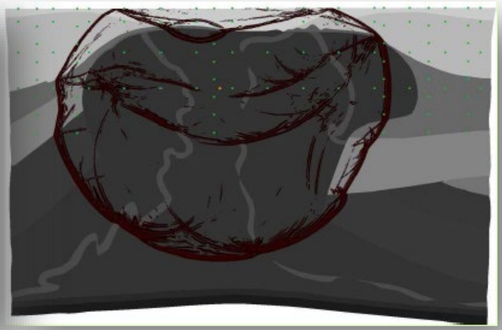
low  hign

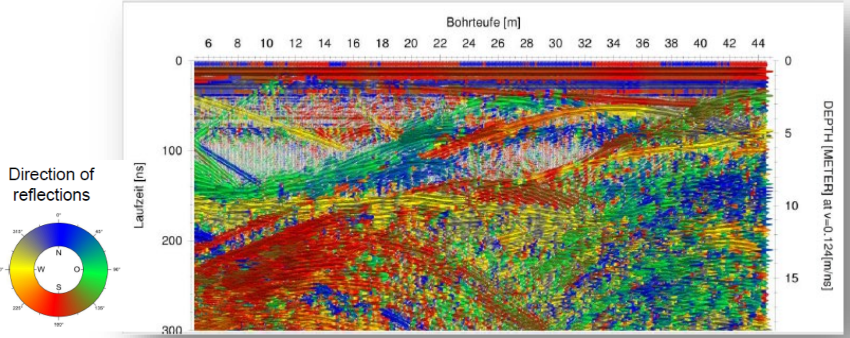
GEOPHYSICAL TECHNIQUES

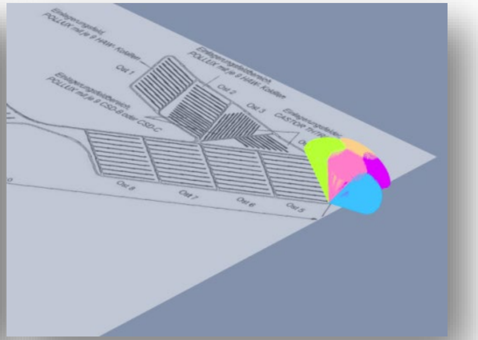
Detection of undeclared / unauthorised activities











Acoustic and seismic monitoring (GER-TU Dortmund)

J. Altmann, H. Kühnicke (2015): **Acoustic and Seismic Measurements for the Detection of Undeclared Activities at Geological Repositories. Results from the Gorleben Exploratory Mine.** JOPAG/11.13-PRG-404

J. Altmann (2015): **Modelling of Seismic-Wave Propagation at a Salt Dome. Final Report.** JOPAG/12.15-PRG-422

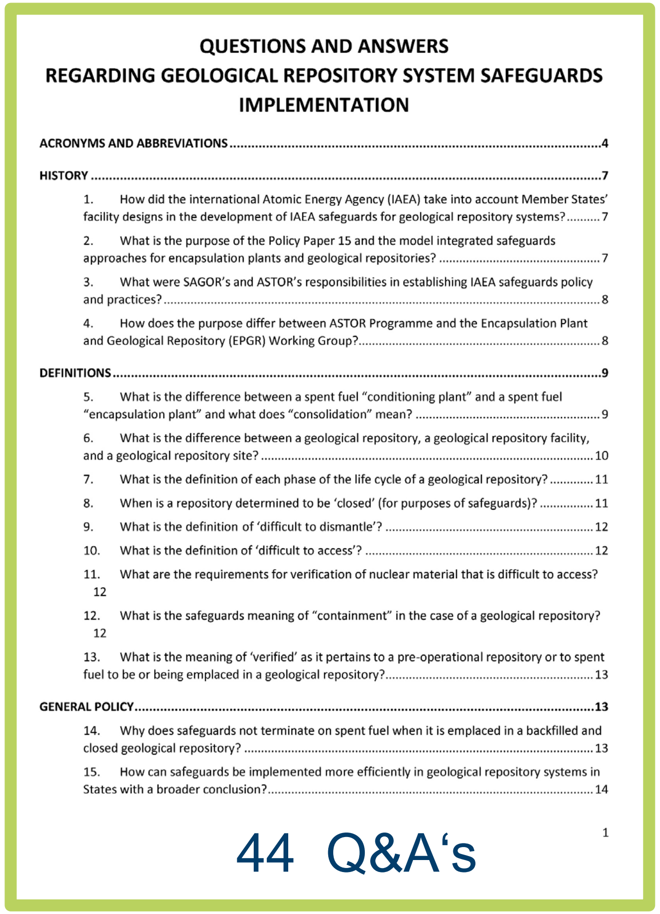
Directive underground radar (GER-DMT)

C. Holst, D. Orlowsky, S. Uchtmann (2017): **Applicability of the directional radar technology for safeguards monitoring nuclear repositories in geological formations.** Proc. ESARDA Symposium, Düsseldorf, 2017

CONSOLIDATION OF SAGOR AND ASTOR RECOMMENDATIONS (2018-2019)

Consolidation

To support the Agency's knowledge management for future generations of safeguards staff in future geological repository programs



QUESTIONS AND ANSWERS
REGARDING GEOLOGICAL REPOSITORY SYSTEM SAFEGUARDS IMPLEMENTATION

1

44 Q&A's

REFERENCE DOCUMENTS

Contents

93 references (incl. abstracts)

CONSOLIDATION OF SAGOR AND ASTOR RECOMMENDATIONS (2018-2019): ACHIEVEMENTS

Consolidation

- Performed diversion path analysis for generic encapsulation plants and geological repositories
- Identified potential safeguards detection points for each facility type and operating phase
- Identified facility-specific technical objectives
- Identified safeguards measures that could be used for each facility
- Developed and assessed a safeguards approach based on IAEA Safeguards Criteria
- Provided input and review of IAEA safeguards policy for spent fuel disposal
- Identified research and development needs and reviewed status of related development tasks
- Supported preparation of a model integrated safeguards approach for each facility type
- Supported preparation and testing of a design information questionnaire for each facility type
- Provided input to a safeguards implementation ‘road map’ developed by the IAEA Department of Safeguards
- Issued a report on the status of technologies that could be used for safeguarding encapsulation plants and geological repositories (STR-384)

FURTHER R&D NEEDS

Technologies

Establish performance requirements for the design of relevant safeguards technologies

Develop and test appropriate safeguards equipment

Implementation

Determine specific information needs of stakeholders and develop appropriate guidance

Develop safeguards approaches under the State-level concept

Develop further approaches on ‘Safeguards-by-Design’ and the ‘Safety-Security-Safeguards’ (3S)

Data and information management

Develop approaches on how information about disposed spent fuel and high-level nuclear waste should be managed, handled, organized, archived, read, interpreted, and secured for the long term (for centuries after repository closure and beyond)

SAFEGUARDING A GEOLOGICAL REPOSITORY IN GERMANY

Responsibilities

Federal Ministry for Economic Affairs and Energy

European Commission

IAEA International Atomic Energy Agency

Germany does not have a national safeguards authority of its own and does not carry out safeguards inspections on its own. Sovereign rights in this field were transferred to the EC (DG Energy, EURATOM). EURATOM is the owner of all nuclear fuel in the EU.

The Federal Ministry for Economic Affairs and Energy (BMWi) holds the overall political responsibility as to maintaining any interferences of safeguards activities with domestic regulations.

EURATOM acts as multinational safeguards authority and is the direct contact for the IAEA on the one hand and the operators on the other within the framework of the verification agreement between the IAEA, EURATOM and the EU member states (INFCIRC/193).

Federal Office for the Safety of Nuclear Waste Management

BGE BUNDESGESELLSCHAFT FÜR ENDLAGERUNG

REFERENCE CONCEPT FOR NUCLEAR MATERIAL SAFEGUARDS IN A GEOLOGICAL REPOSITORY FOR SPENT NUCLEAR FUEL (1993)

[JOPAG/12.93-PRG-205, 1993]

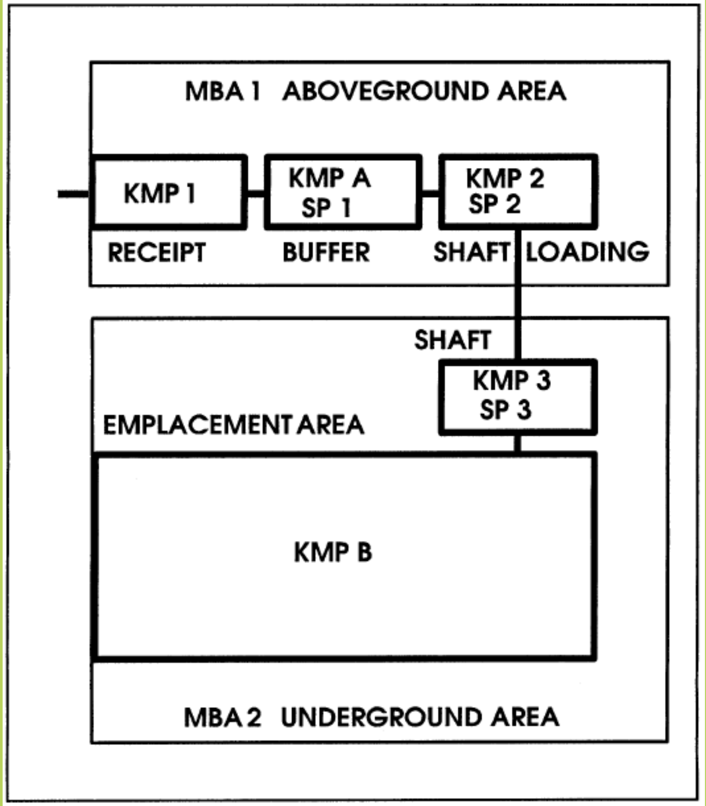


Figure 4: Safeguards concept for final disposal in a geological repository

KMP: Key Measurement Point
MBA: Material Balance Area
SP: Strategic Point

MBA 2:

- Accounting and re-examination of the plant design data
- No containment/surveillance measures
- No inspection activities

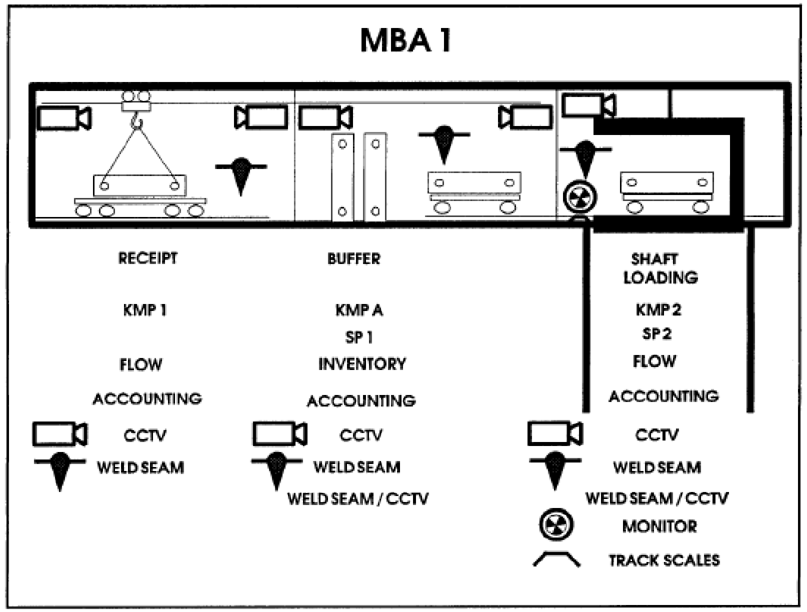


Figure 5: Possible safeguards measures for MBA 1

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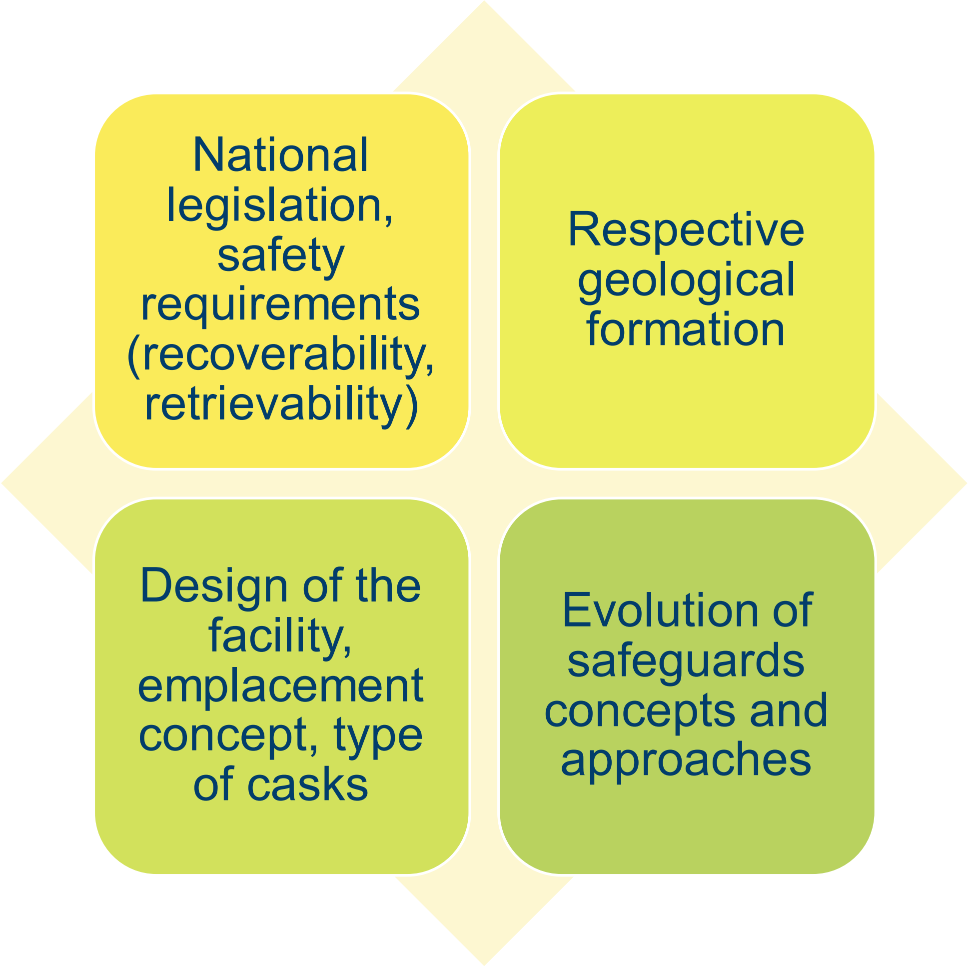
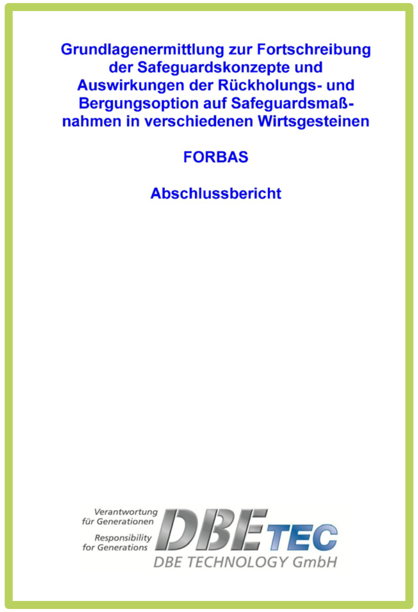
UPDATING THE SAFEGUARDS CONCEPT

Taking into account the 2010 safety requirements (recoverability, retrievability)





Grundlagenermittlung zur Fortschreibung der Safeguardskonzepte und Auswirkungen der Rückholungs- und Bergungsoption auf Safeguardsmaß-nahmen in verschiedenen Wirtsgesteinen

FORBAS

Abschlussbericht

Verantwortung für Generationen
Responsibility for Generations
DBE TEC
DBE TECHNOLOGY GmbH

The State-level approach (SLA) for Germany will address the safeguards measures and activities for the geological repository. The given SLA for Germany will be updated in the different lifecycle phases of the repository.

Thank you for your attention.

Dr. Irmgard Niemeyer
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Email: i.niemeyer@fz-juelich.de