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Session "Safeguards, Decontamination & Decommissioning"

Towards a '3S toolbox' for providing safety, security and safeguards at geological disposal of high-level radioactive waste and spent fuel

Oct 31, 2017 | **Irmgard Niemeyer**, Guido Deissmann, Dirk Bosbach
IEK-6: Nuclear Waste Management and Reactor Safety
Forschungszentrum Jülich GmbH
Germany

Towards a '3S toolbox' for providing safety, security and safeguards at geological disposal of high-level radioactive waste and spent fuel

1

Introduction – bridging safety, security and safeguards (3S)

2

Integration of 3S at geological disposal

3

Towards a 3S toolbox

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The three main pillars of nuclear operations

Safety



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Operational safety

Achievement of proper operating conditions, prevention of accidents or mitigation of accident consequences, resulting in protection of workers, the public and the environment from undue radiation hazards.

Security

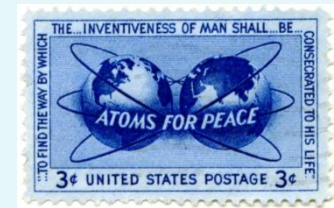


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Physical protection

Prevention and detection of, and response to, theft, sabotage, unauthorized access, illegal transfer or other malicious acts involving nuclear material, other radioactive substances or their associated facilities.

Safeguards

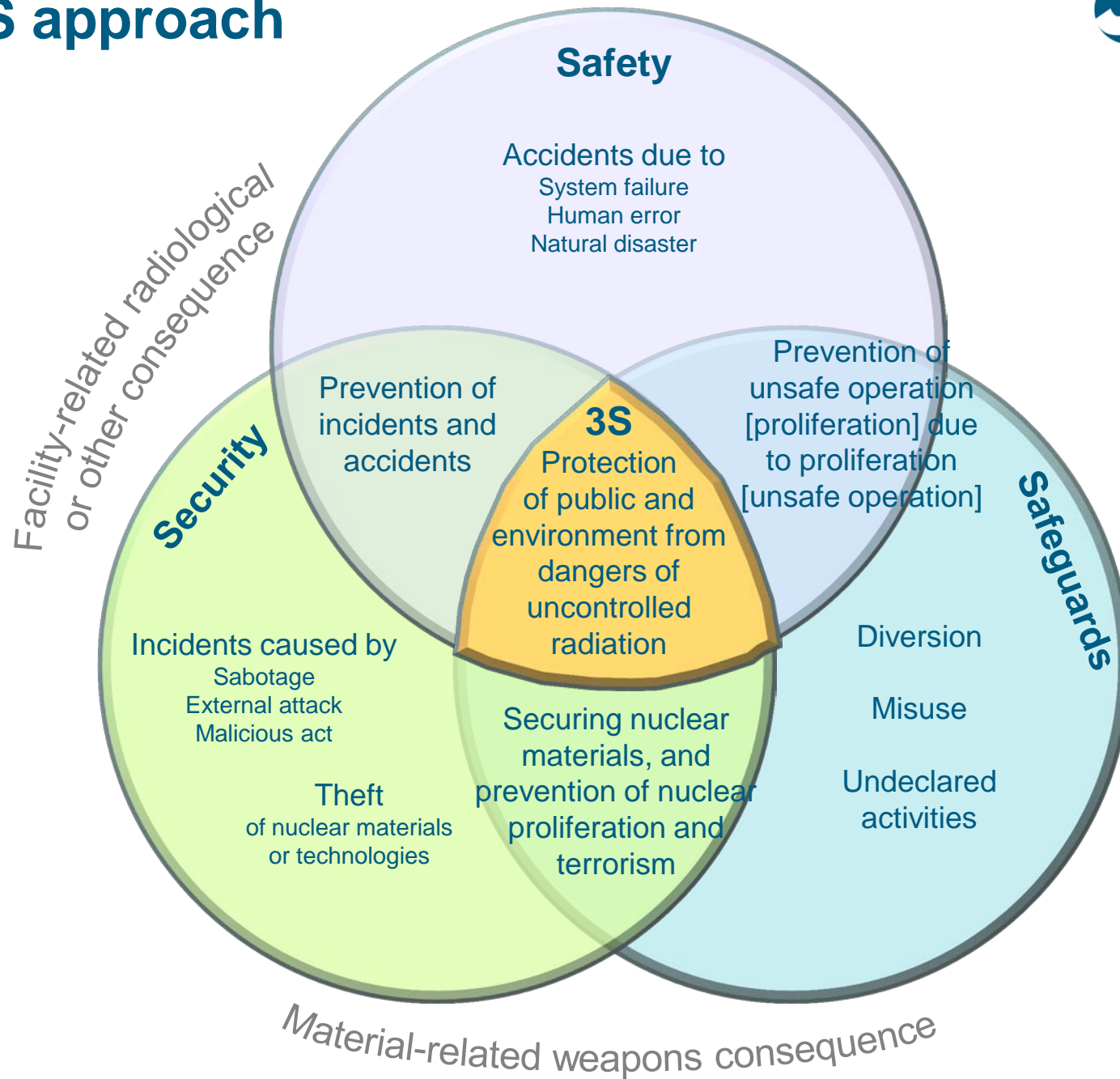


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Non-proliferation

Measures to ensure that nuclear materials and facilities under IAEA control are not used in such a way as to further any military purpose.

3S approach



Towards a '3S toolbox' for providing safety, security and safeguards at geological disposal of high-level radioactive waste and spent fuel

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[Niemeyer, I., Deissmann, G., Bosbach, D., Bridging nuclear safety, security and safeguards at geological disposal of high-level radioactive waste and spent nuclear fuel, In: International Conference on the Safety of Radioactive Waste Management, IAEA-CN-242, 21-25 November 2016, Vienna, Austria, Book of Paper, Session 3d, p.20-24].

Safety, security and safeguards principles of geological disposal

Safety

Protection of people and the environment against the dangers arising from ionising radiation



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Isolate
Contain
Retard

Security

Preventing malicious acts involving nuclear or radioactive material by terrorists

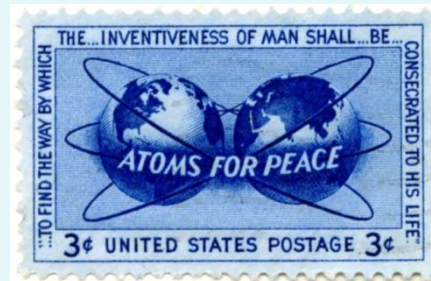


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Prevent
Detect
Respond

Safeguards

Preventing the spread of nuclear weapons by States



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Deter
Timely detect

Safety, security and safeguards principles of geological disposal

Safety

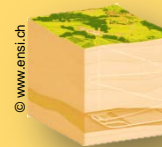
Protection of people and the environment against the dangers arising from ionising radiation

Security

Preventing malicious acts involving nuclear or radioactive material by terrorists

Safeguards

Preventing the spread of nuclear weapons by States



3S principles

Protection of public and environment from dangers of uncontrolled radiation

Contain

Prevent

Detect



3S framework

New or revised nuclear legislation on geological disposal of high-level radioactive waste and spent nuclear fuel should also take 3S conflicts and interfaces into account.

Safety

Convention of Nuclear Safety (CNS)
Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management
...
National legislation and law enforcement

Security

Convention on the Physical Protection of Nuclear Material (CPPNN)
UN Security Resolutions 1373 and 1540
...
National legislation and law enforcement

Safeguards

Non-proliferation Treaty (NPT)
Regional Treaties (e.g. Euratom Treaty)
Safeguards Agreements between States and IAEA
Additional Protocol to Safeguards Agreements
National legislation

Different responsibilities of national governments, appointed regulatory bodies and facility operators.

Radionuclides subject to safety, security, safeguards

“3S Radionuclides”



U chain, Pu chain

Long-lived radionuclides, i.e. actinides, long-lived fission products, long-lived activation products.

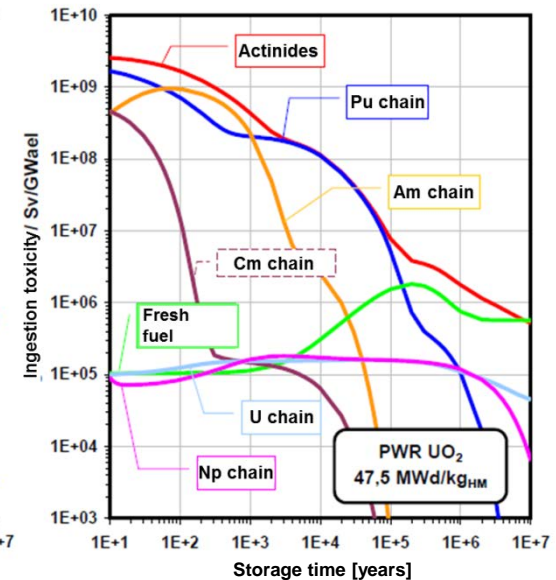
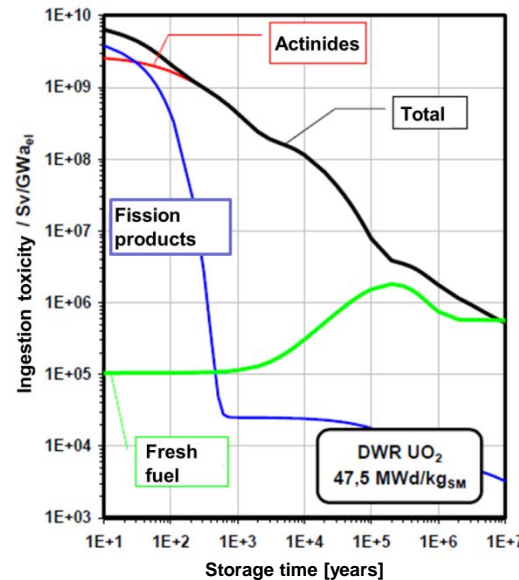
Safety

Nuclear material and other radioactive material

Security

Nuclear material*

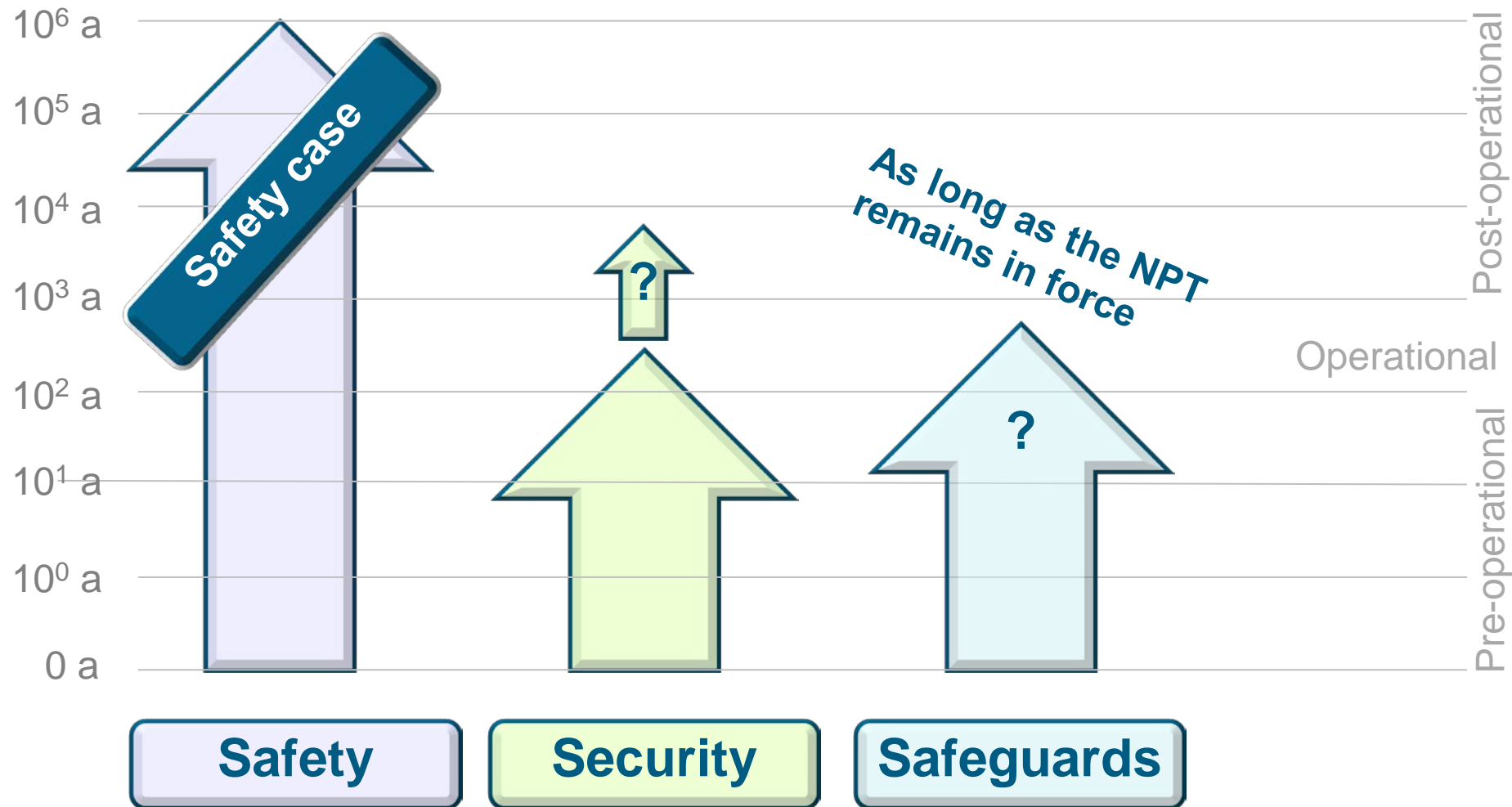
Safeguards



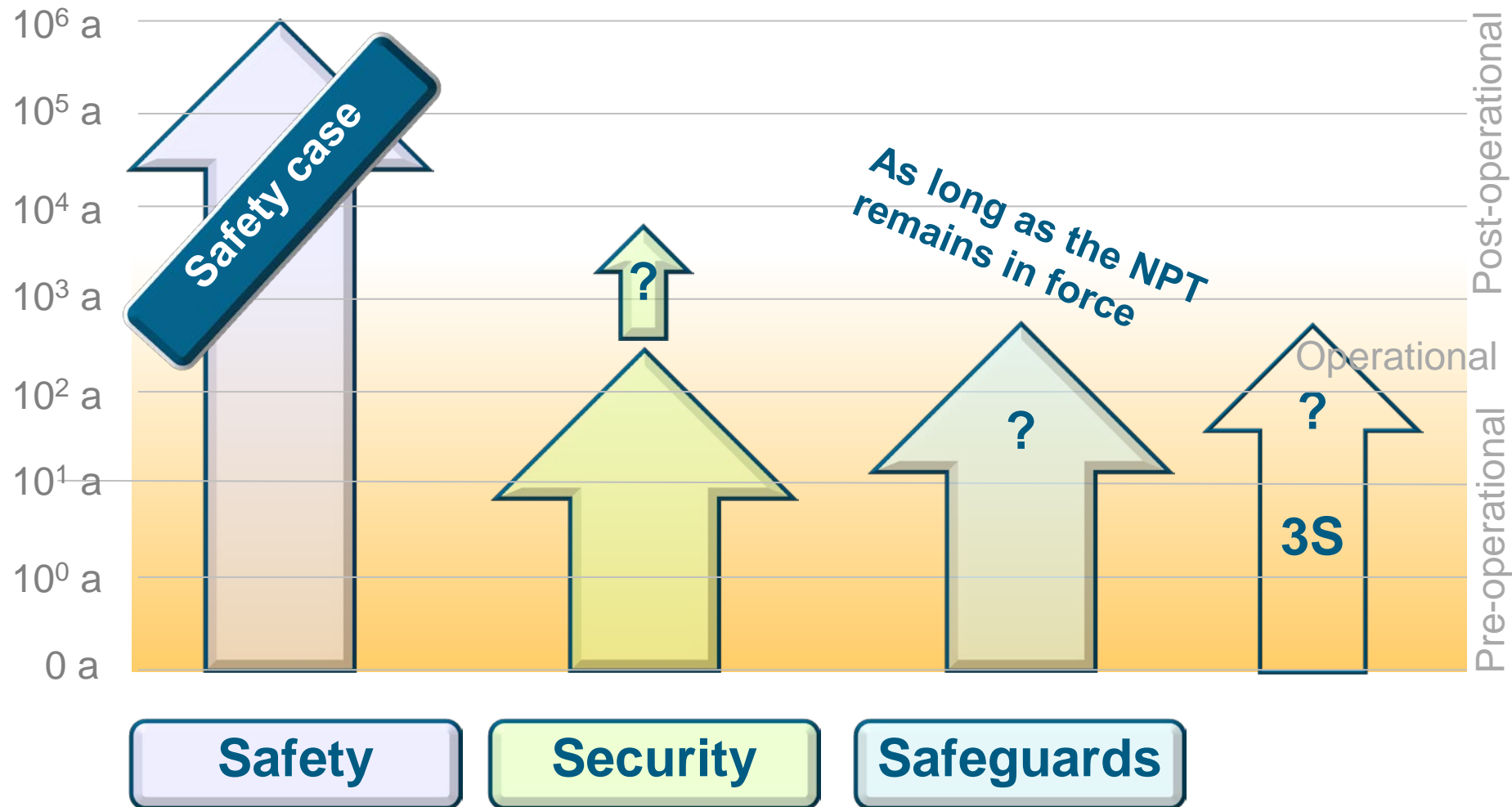
Figures modified after Modolo (2014)

**) “Plutonium except that with isotopic concentration exceeding 80% in plutonium-238; uranium-233; uranium enriched in the isotope 235 or 233; uranium containing the mixture of isotopes as occurring in nature other than in the form of ore or ore residue; any material containing one or more of the foregoing.” [IAEA Safety Glossary, 2016]*

Timelines of geological disposal



Timelines of geological disposal





**‘Safety, security and safeguards by Design’
(3SBD):** early consideration of 3S in the design phase

Facility should be inherently
safe, secure and
proliferation-resistant

reversibility,
including
post-closure
retrievability

safety
security
safeguards

long-term
(post-closure)

operational
safety
requirements

Control measures at geological disposal sites



Intrusive methods relying on the emplacement of instrumentation in the isolation barriers would not be acceptable.

Safety

Safety case

Safety assessment

Intrinsic, passive controls:

- engineered features
- engineered and geological barriers

Active control:

- unattended monitoring
- environmental sampling

Security

Nuclear material accountancy system

Monitoring security systems

Personnel entry controls

Detection and surveillance

Detection and response (alarm/alert)

Safeguards

Nuclear material accountancy system

SF measurements before encapsulation (at pin level accuracy): e.g. PGET

Design information verification (3D laser scan.)

Containment & surveillance (including remote data transmission)

Unattended monitoring

Environmental sampling

Geophysical monitoring

Satellite imagery analysis

Continuity of knowledge

Active measures

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Towards a 3S toolbox



Design Information Verification, e.g.

- 3D Laser Scanning
- Simultaneous Location and Mapping (SLAM)

Non-Destructive Assay Verification, e.g.

- Gamma Emission Tomography (GET)
- Passive Neutron Albedo Reactivity (PNAR)
- Differential Die-Away Self-Interrogation (DDSI)
- Self-Indication Neutron Resonance Densitometry (SINRD)
- Digital Cerenkov View Device (DCVD)

Containment & Surveillance, e.g.

- Ultrasonic Optical Sealing Bolt (UOSB)
- Laser Surveillance System (LASSY)
- Ultrasonic Identification and Authentication of Copper Canisters
- Tungsten-Based Identifiers

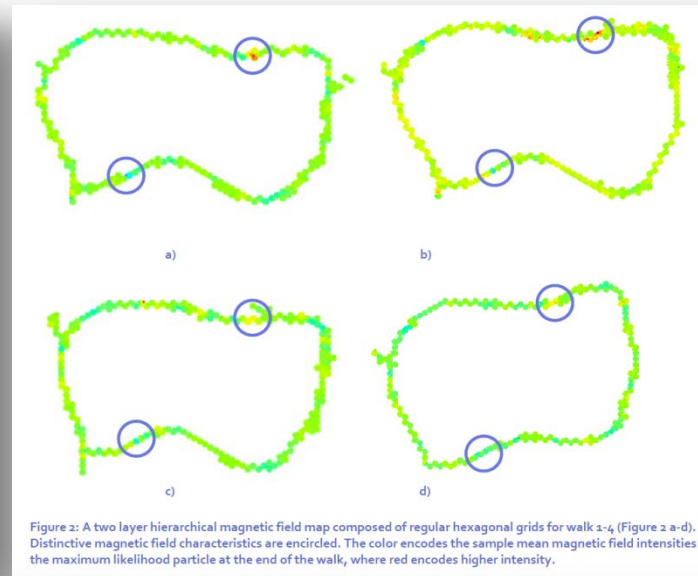
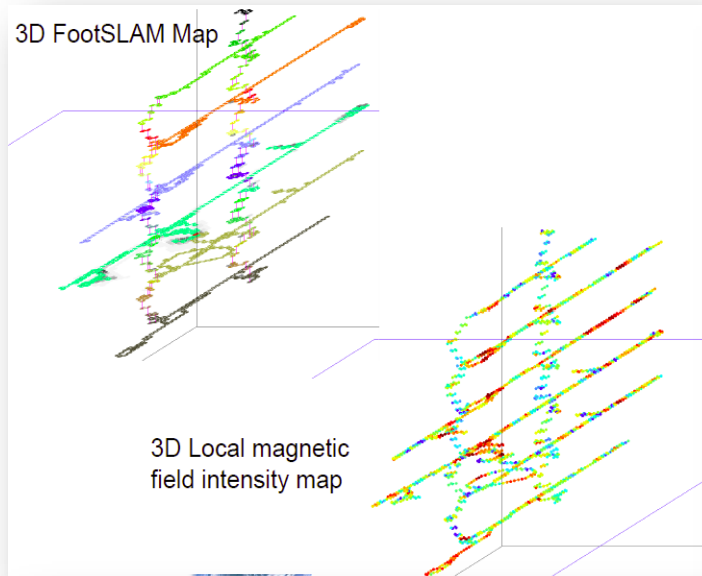
Satellite Imagery & Geophysical Techniques, e.g.

- Automated optical & SAR satellite data change detection
- Seismic monitoring
- Directional Radar Technology

“Application of Safeguards to Geological Repositories” (ASTOR), Group of Experts: IAEA, EC + Member States BEL, CAN, CZR, FIN, FRA, GER, HIN, JPN, KOR, NED, RSA, ESP, SWE, USA (SWI, UK)

Design information verification (DIV)

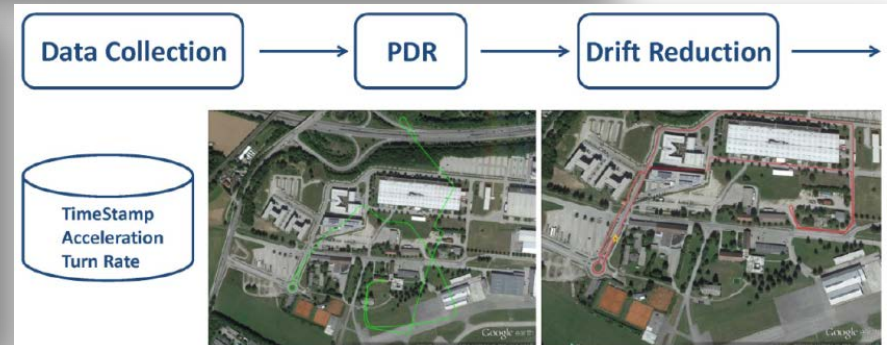
Detection of undeclared constructions



MEMS Mti Xsens
(www.xsens.com)



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



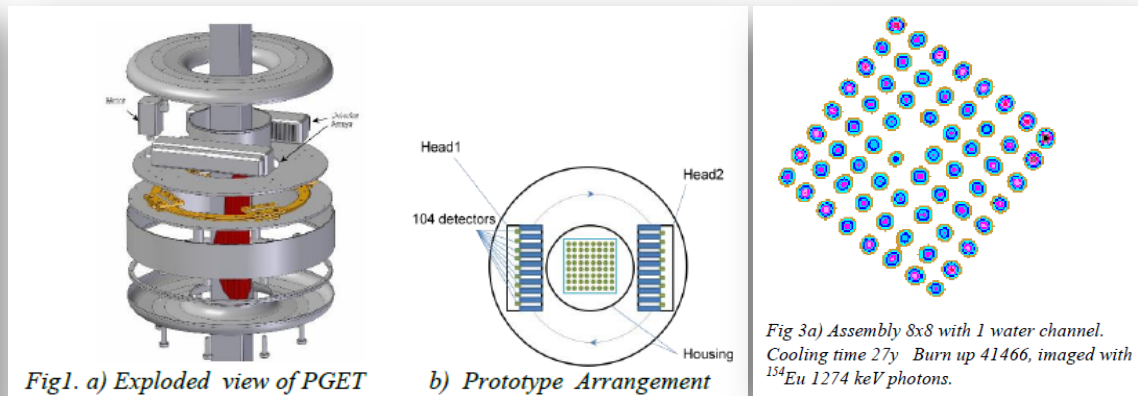
Simultaneous location and mapping (SLAM) (GER-DLR)

Non-destructive assay techniques (NDA)

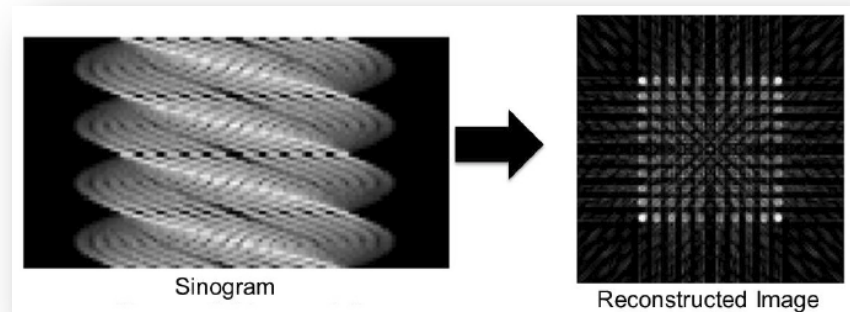
Spent fuel verification (partial defect – detection of a single missing pin inside a fuel assembly)



© JRC Ispra



[Source: Honkamaa et al., Proc. IAEA Safeguards Symposium 2014]



[Source: Svärd et al., Proc. ESARDA Symposium 2017]

Passive Gamma Emission Tomography (PGET) (FIN, SWE, USA)

Continuity of knowledge

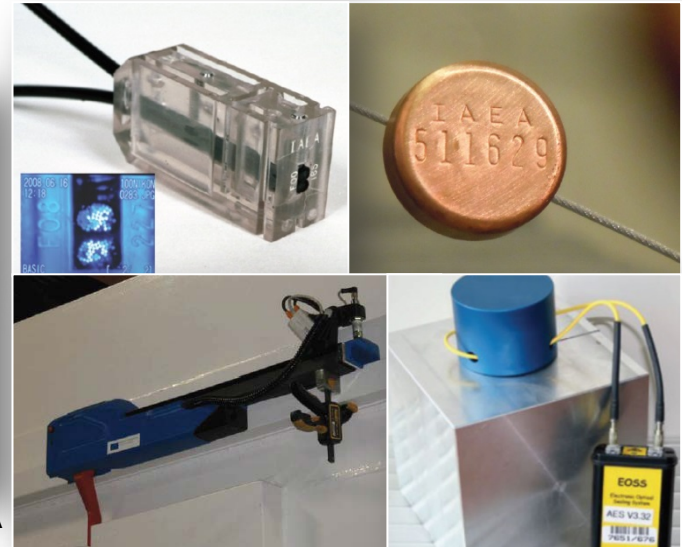
- Existing sealing systems: Cobra V, Active Optical Loop Seal, Glass Seal, Ultrasonic Optical Sealing Bolt, EOSS,...
- Existing surveillance systems: Next Generation Surveillance Camera (NGSS)
- Requirements: Low maintenance and service needs, remote data transmission



© Dr. Neumann



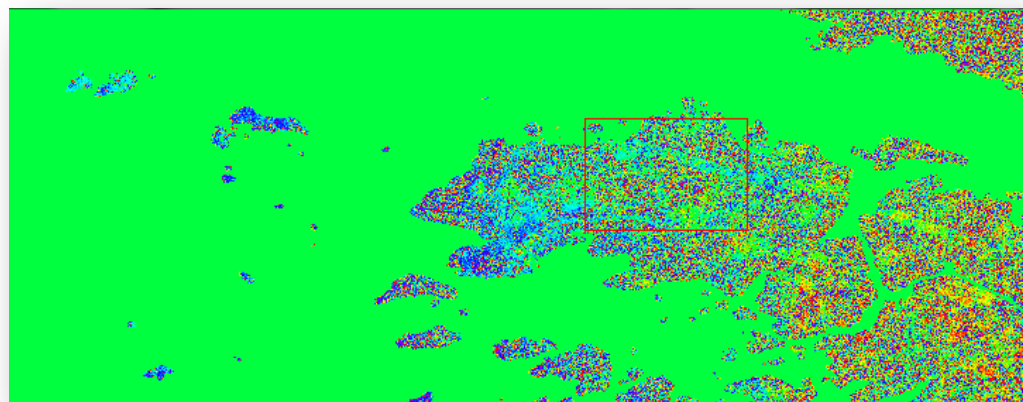
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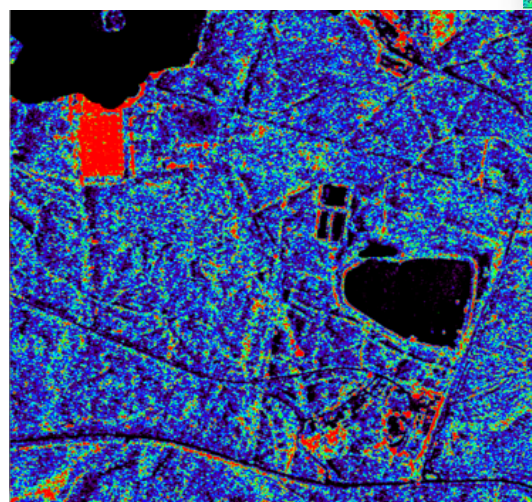
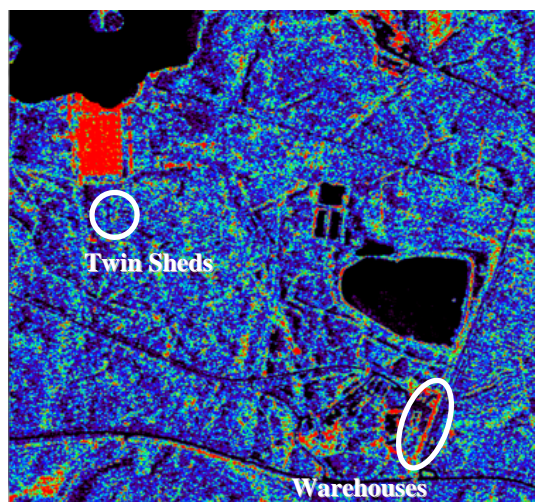
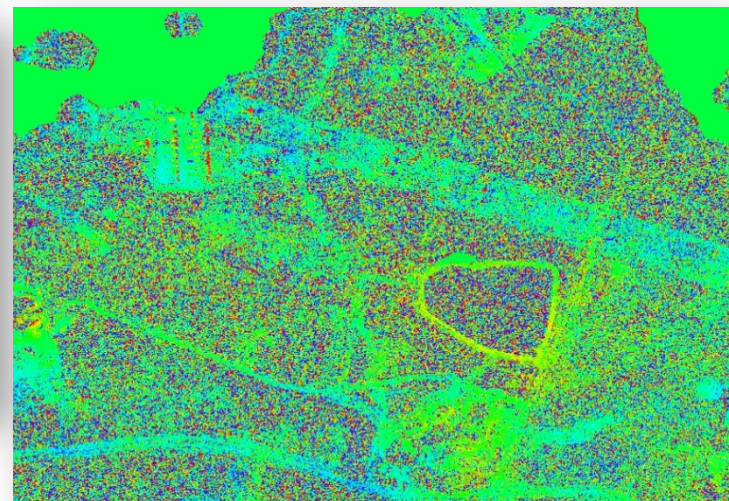
Optical surveillance, sealing systems, remote data transmission

Satellite imagery (SI)

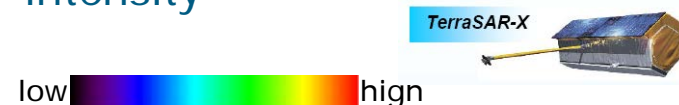
Change detection, deformation analysis



-2π  2π



TerraSAR-X images
acquired at May 23
(right) and June 3 (left)
Top: Interferogramm
Left: Color-coded backscatter
intensity

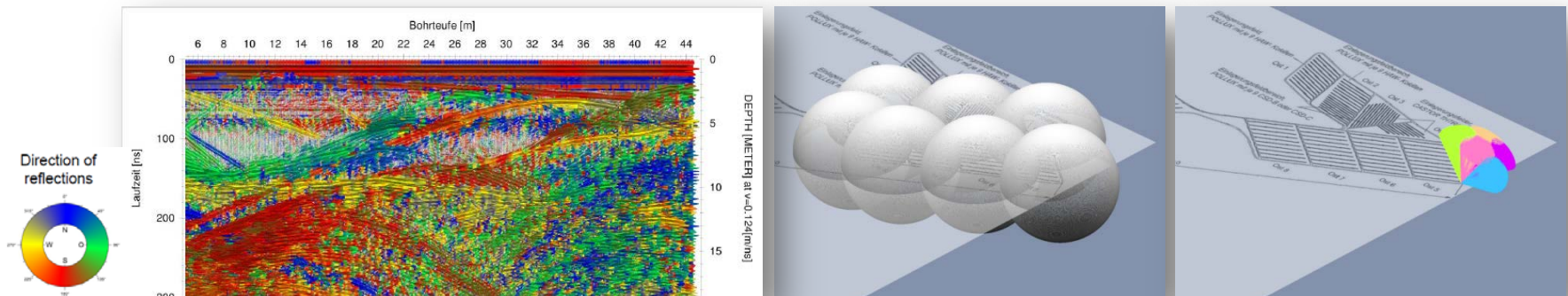
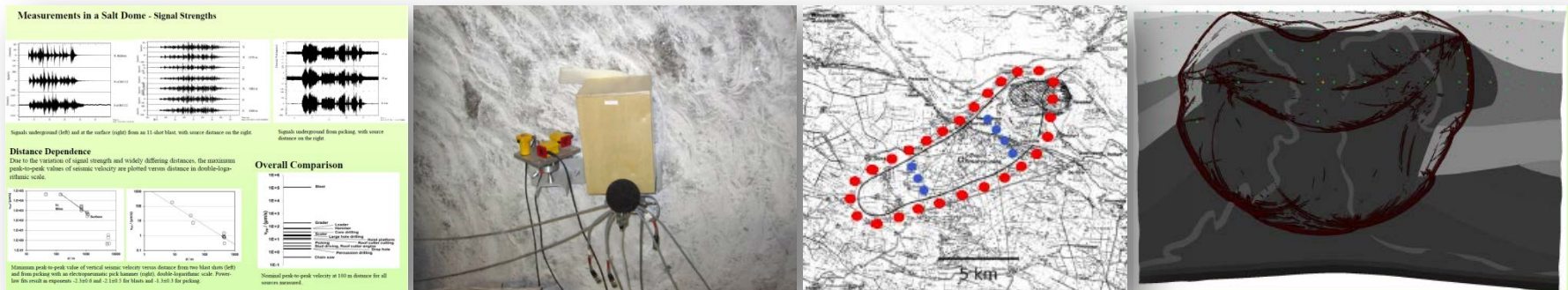


Application of SAR interferometry and non-coherent change
detection techniques (CAN/FIN/GER-Jülich/JPN)

Geophysical techniques (GT)

Detection of undeclared activities

Acoustic and seismic monitoring (GER-TU Dortmund)

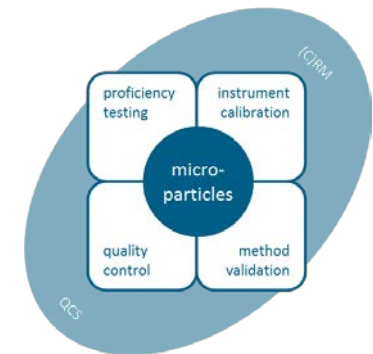
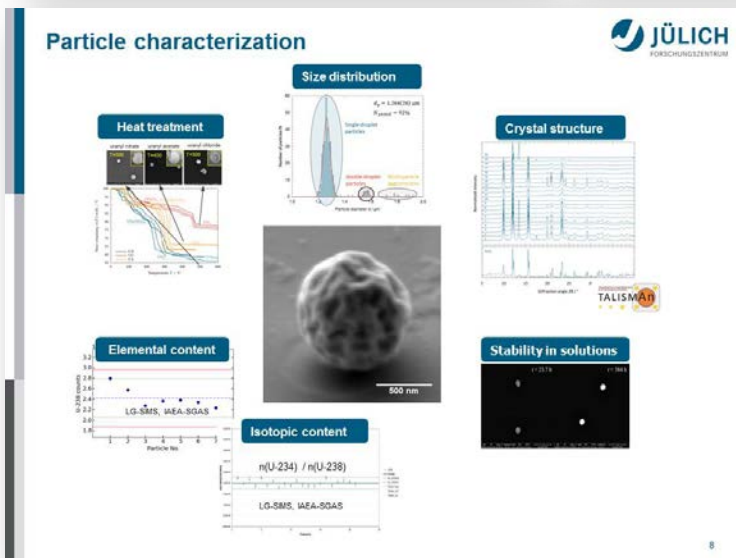
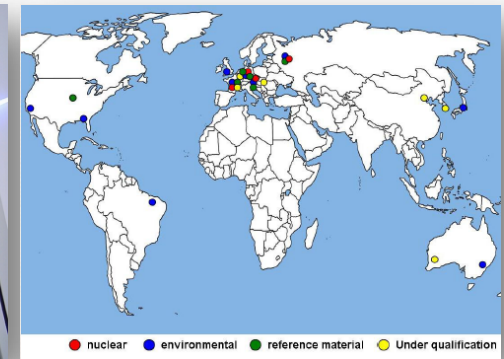


Directive underground radar (GER-DMT)

Environmental sampling (ES)

Detection of undeclared activities

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→ Stefan Neumeier, 10:15

Particle analysis of environmental swipe samples – Provision of reference materials (GER-Jülich)

Summary – Synergies and conflicts

	Safety	Security	Safeguards
DIV			
NDA			
C/S			
SI			
GT			
ES			

Synergies

Synergies / Conflicts

Conflicts

N/A



Further R&D needed to identify concepts, methods and technologies that would be best suited for the holistic consideration of safety, security and safeguards provisions of geological disposal.



Bridging safety, security and safeguards in **research funding and research activities** related to geological disposal needed.

Thank you for your attention.

Dr. Irmgard Niemeyer
Head International Safeguards Team

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

Email: i.niemeyer@fz-juelich.de