Technische Universität Braunschweig

ENTRIA

ENTSORGUNGSOPTIONEN FÜR RADIOAKTIVE RESTSTOFFE: INTERDISZIPLINÄRE ANALYSEN UND ENTWICKLUNG VON BEWERTUNGSGRUNDLAGEN

Technical concepts for storing HLW - Monitoring, renewal and refurbishment of storage facilitites

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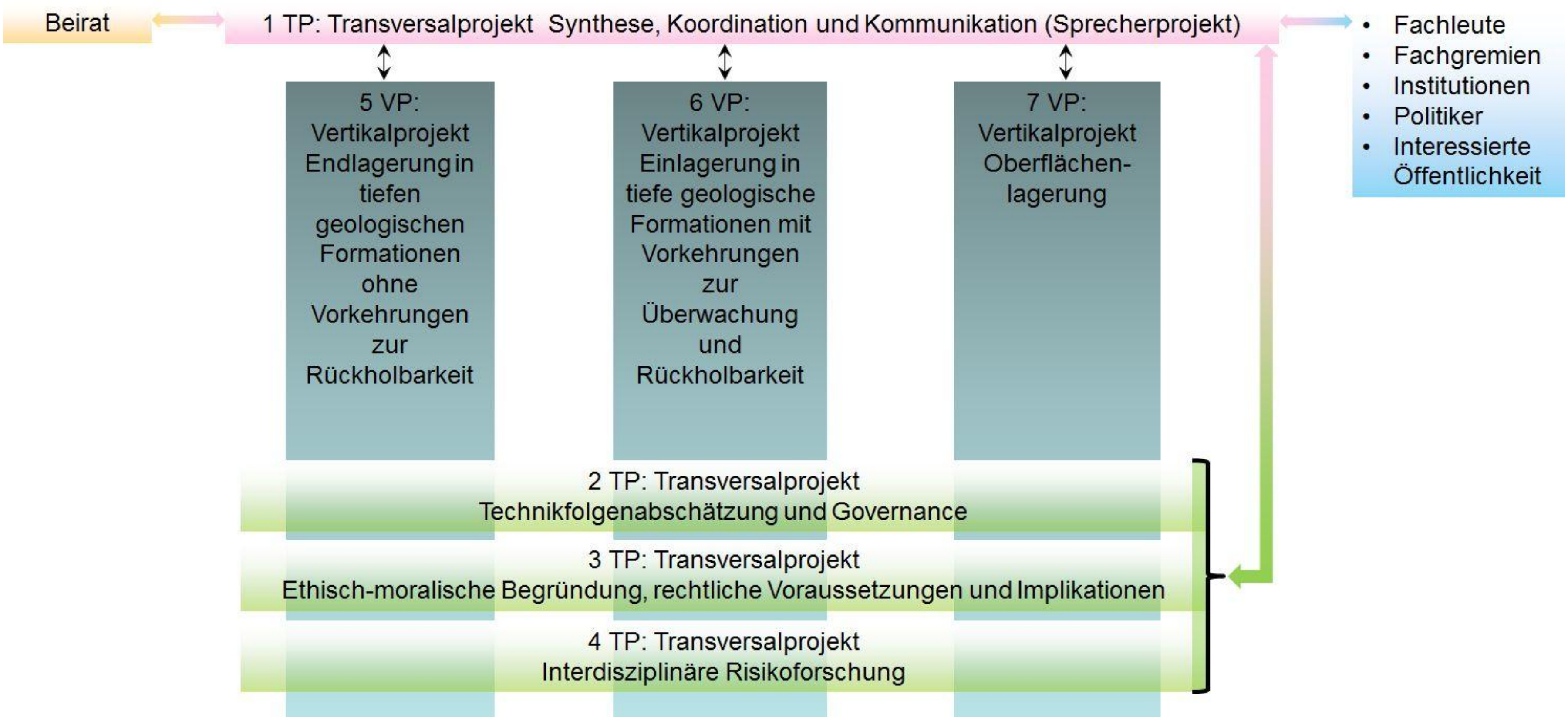
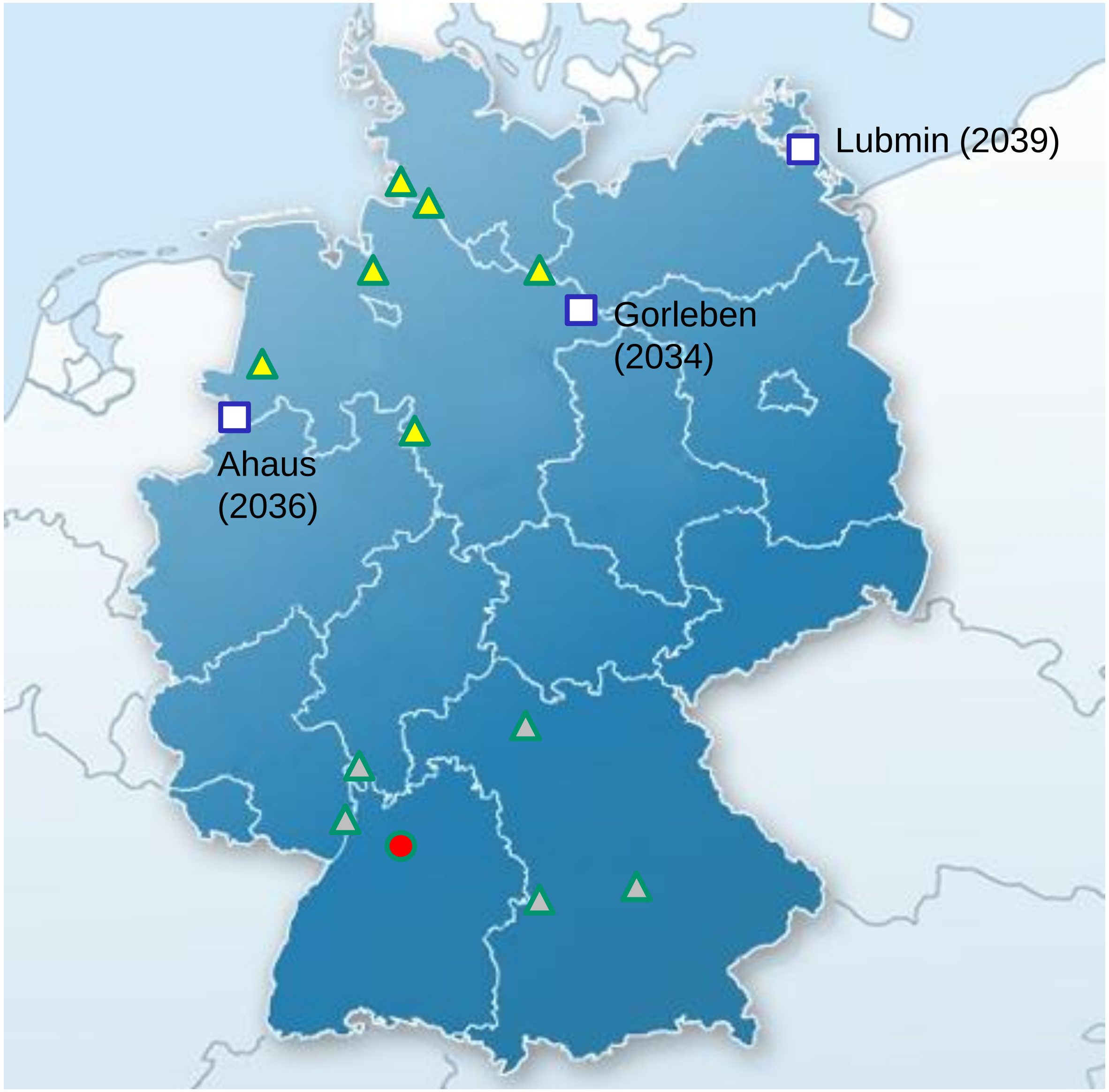
Organisation within ENTRIA



WP 7.1: Civil Engineering Concepts
WP 7.2: Probabilistic, monitoring-based Safety- and Life-Cycle-Concept
WP 7.3: Requirements due to Methods of Waste Treatment

Interim storage in Germany



Since 1960's:
Disposal in deep geological formations planned as the final step of radioactive waste management

Site Selection Law (2013):
Site selection for the future repository for heat-generating radioactive waste should be finished by 2031.

Example for the **timespan** between site selection and start-up:
Repository for not heat-generating radioactive waste **„Schacht Konrad"**: Start of the licensing procedures in 1982. Estimated beginning of disposal in 2022.

Centralized storage facility □
Decentralized storage facility:
WTI-Concept △
STEAG-Concept △
Tunnel-Concept ●

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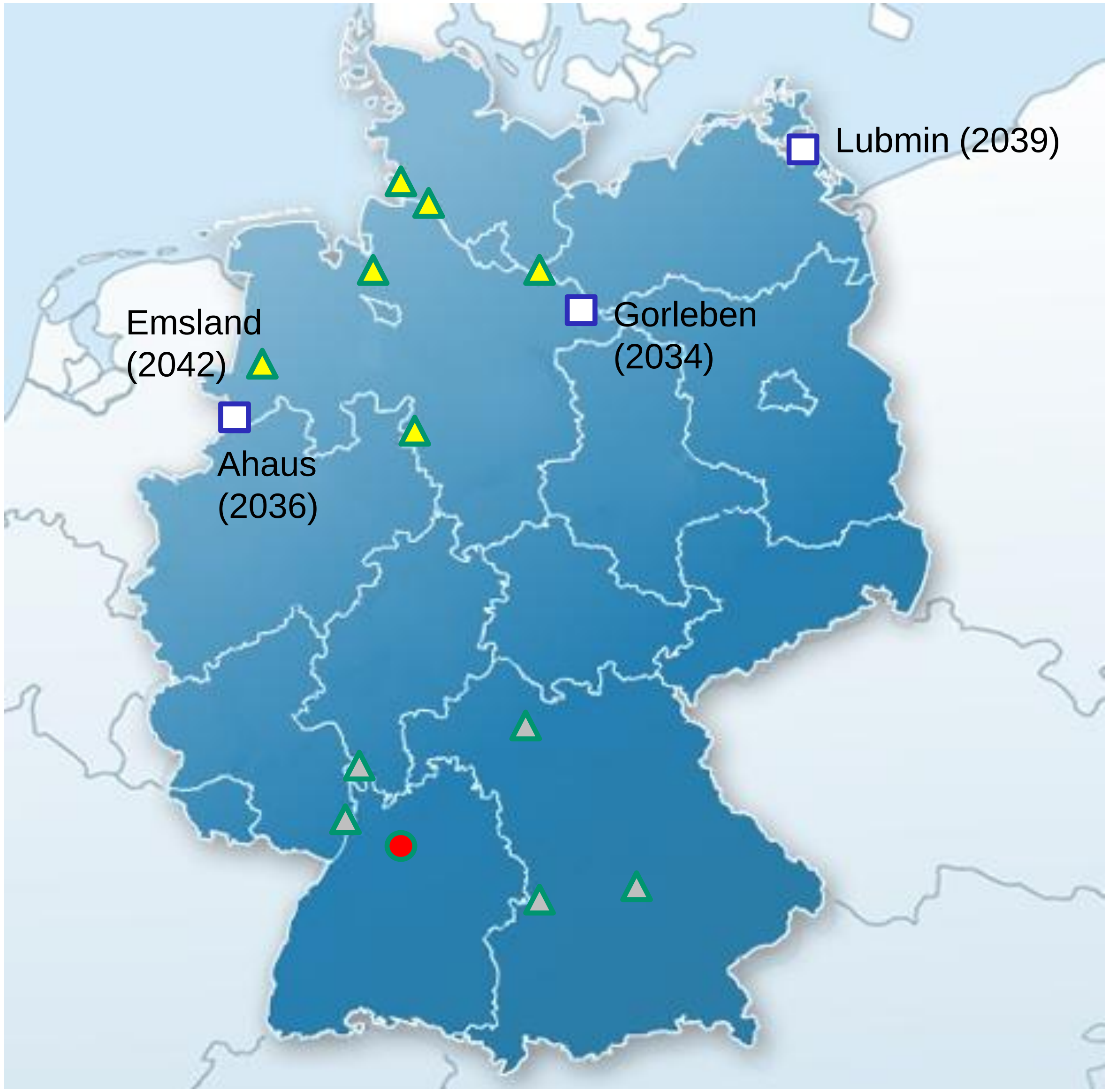

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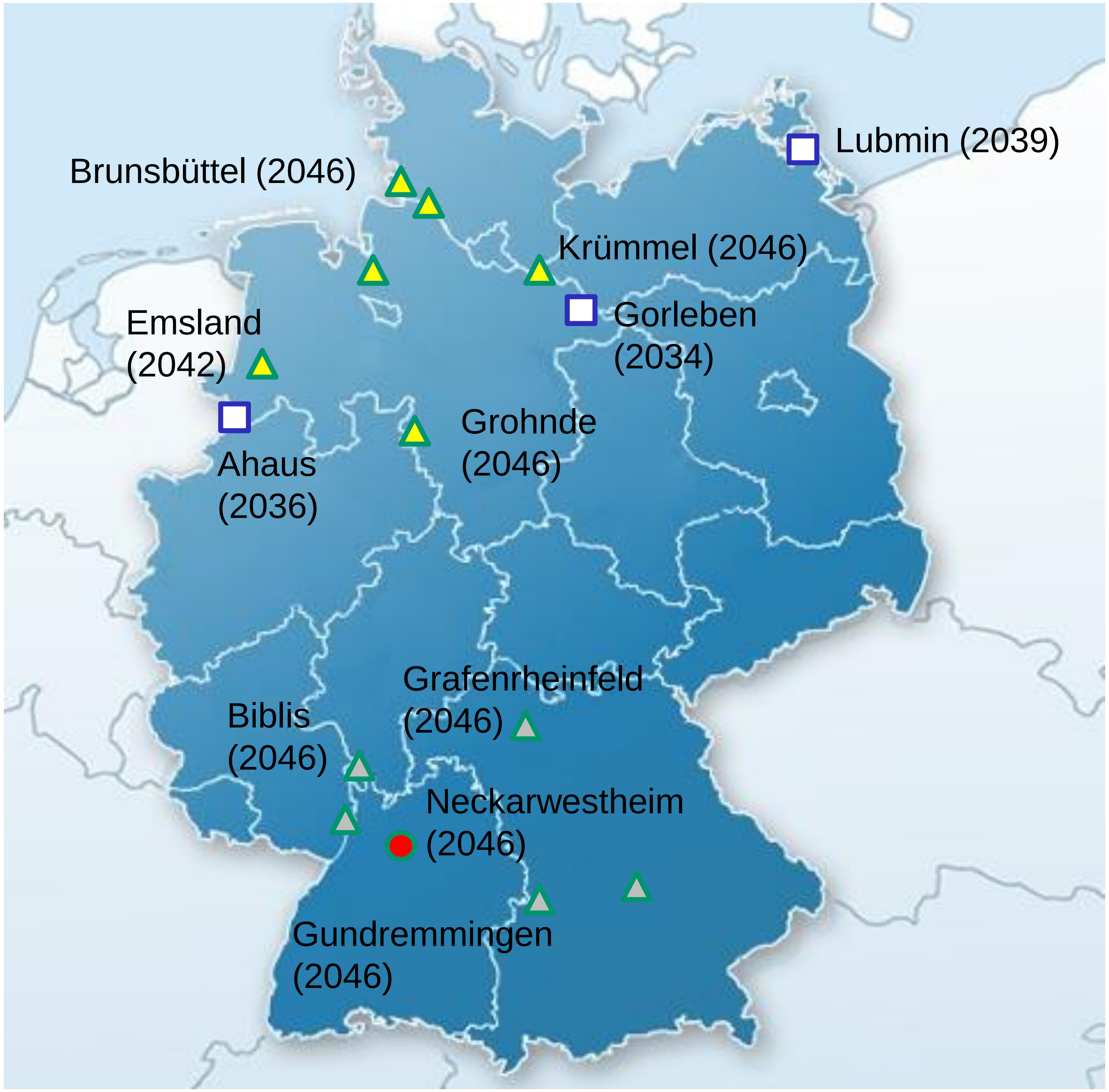

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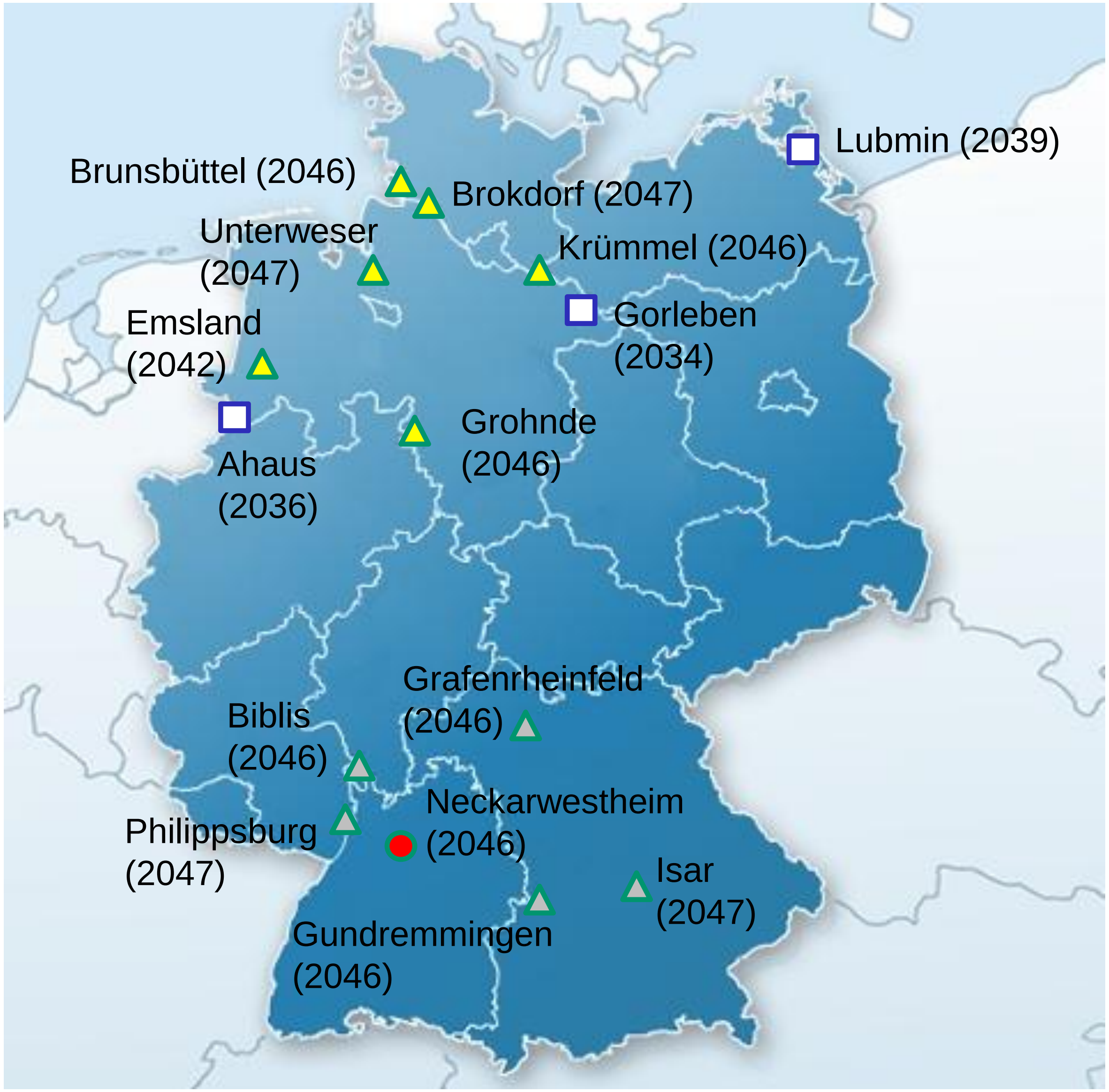

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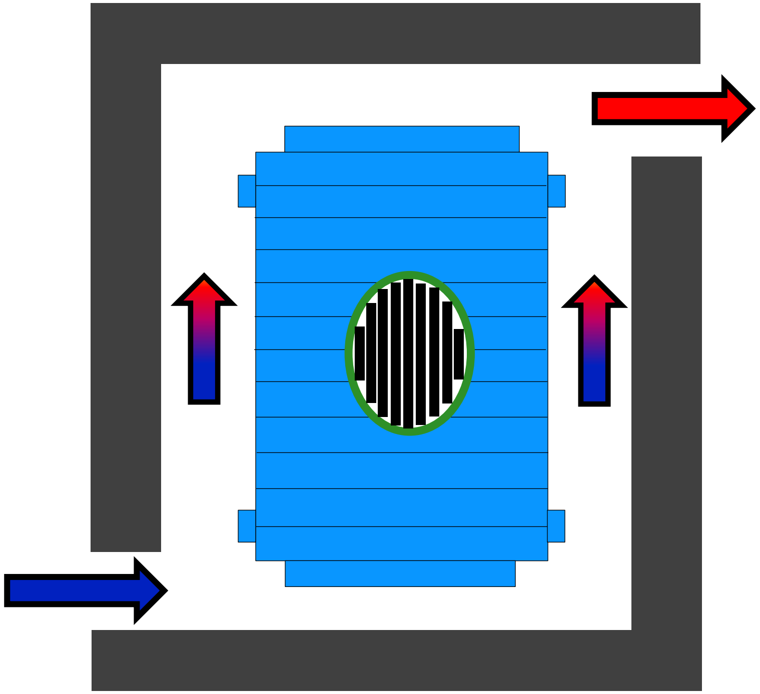
Which requirements have to be met?

IAEA Safety Standards [SF-1]:

„The **fundamental safety objective** is to protect people and the environment from harmful effects of ionizing radiation“

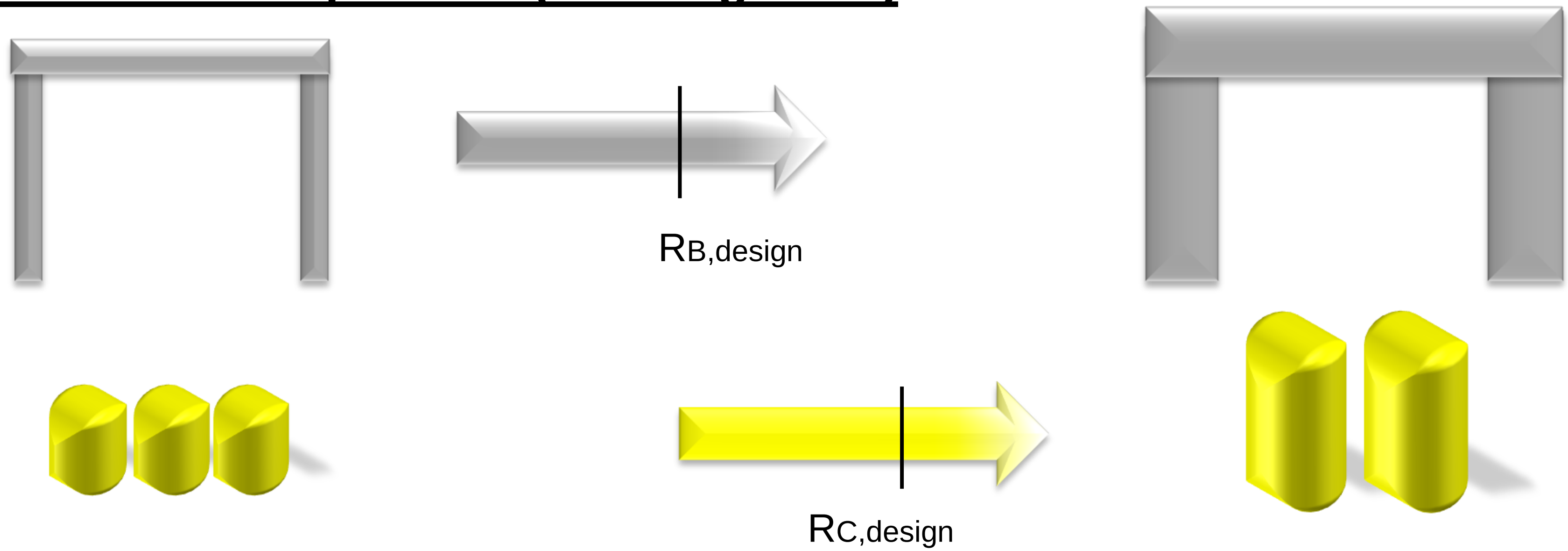
Ensured by:

- Radiaton shielding
- Safe enclosure
- Removal of decay heat
- Subcriticality

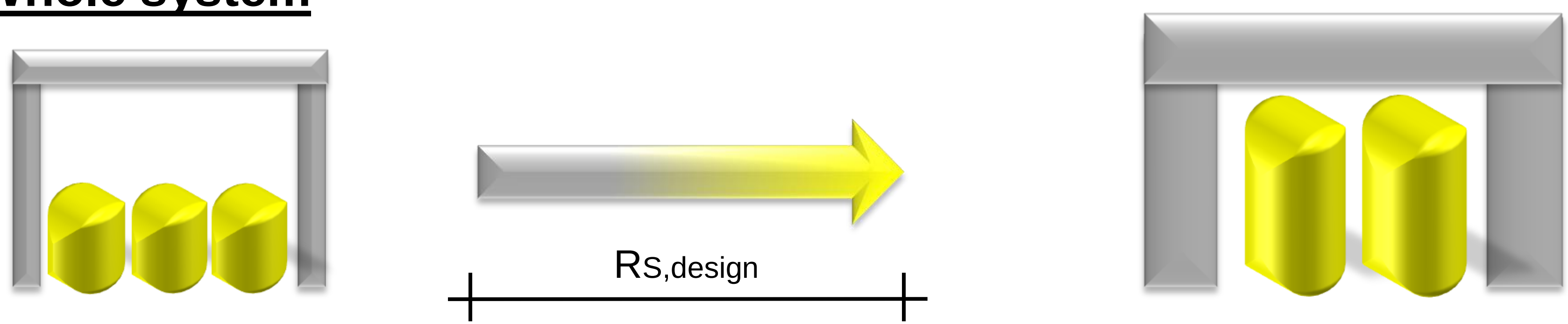


Resistance of storage facilities

Individual components (Building/Cask)



Whole system



General storage concepts – Part 1

Referring to [1], [2]

Type	Option	Examples
Independent Spent Fuel Storage Pool (**Wet** Storage of Spent Fuel)	**Water** in a deep stainless steel lined **concrete pool within an enclosed structure**	Most ARs + many AFRs worldwide
Vertical Dual-Purpose Spent Fuel **Dry Storage/Transfer Cask**	**Heavily shielded steel cask** with spent fuel sealed **in inner steel canister** (i.e. double-lidded)	CASTOR, TN, NAC-ST/STC, BGN Solutions
Concrete **Dry** Storage **Vault** with Thimble Tube Storage Wells	**Heavily shielded concrete vault** with **thimble tube storage wells** for spent fuel	MVDS, MACSTOR, HABOG

Centralized **wet** storage facility (Oskarshamm, S) [3]

Decentralized storage facility for **dual-purpose casks** (Krümmel, D) [4]

Centralized **vault** storage facility HABOG (Vlissingen, NL)

General storage concepts - Part 2

Referring to [1], [2]

Type	Option	Examples
Vertical Concrete **Dry** Spent Fuel Storage Cask/Silo	**Heavily shielded concrete cask/silo** with spent fuel sealed in an **inner steel canister**	CONSTOR, HI-STORM
Horizontal Modular Concrete **Dry** Spent Fuel Storage	**Heavily shielded modular concrete storage** with spent fuel sealed in an **inner steel canister**	NUHOMS, NAC-MPC/UMS, MAGNASTOR
Dry Geologic Storage (Tunnel or Mine)	Dry gas-filled spent fuel canisters emplaced in an isolated deep tunnel or mine and backfilled with earth	

HI-STORM **Vertical** storage **cask** [5]

NUHOMS **Horizontal** storage **module** [6]

HABOG at Vlissingen, NL

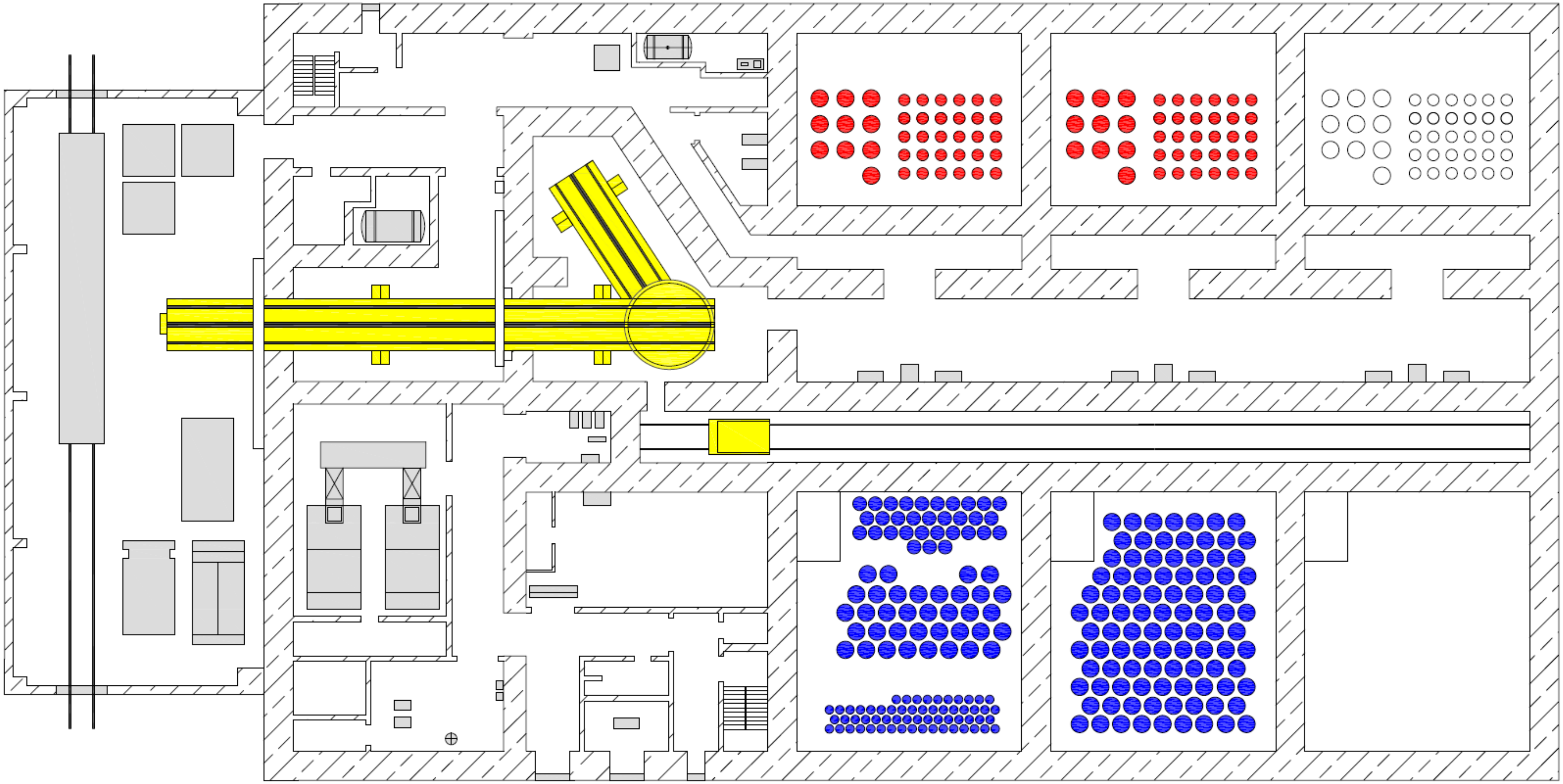
COVRA: Centrale Organisatie voor Radioactief Afval
(Central Organisation for Radioactive Waste)

HABOG: Hoogradioactief Afval Behandeling- en Opslag Gebouw
(High Level Waste Treatment and Storage Building)

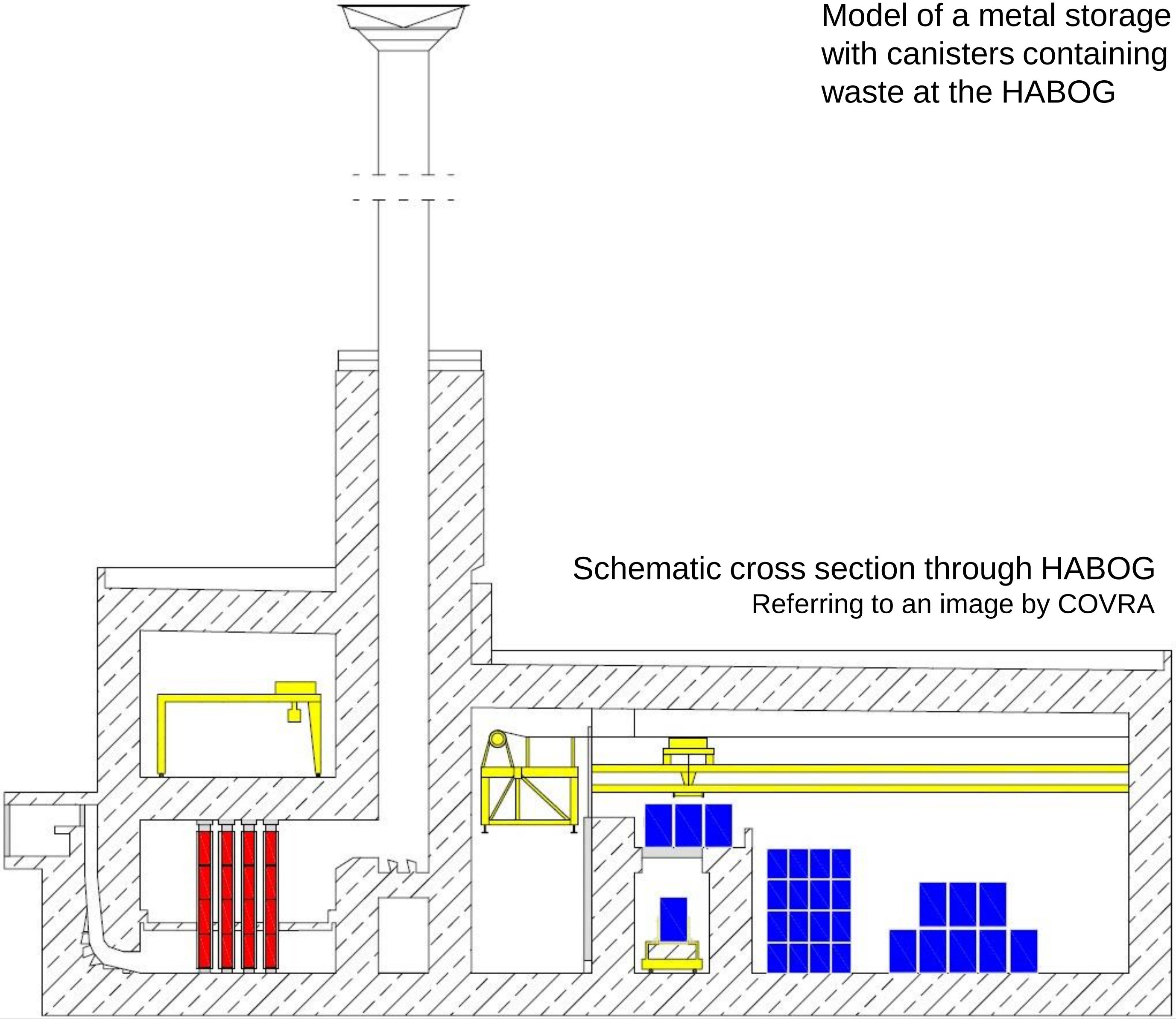
Design of the HABOG at Vlissingen, NL

Storage of heat-generating/not heat-generating high level waste in different storage modules

Referring to an image by COVRA



Design of the HABOG at Vlissingen, NL



Model of a metal storage tube filled with canisters containing vitrified waste at the HABOG

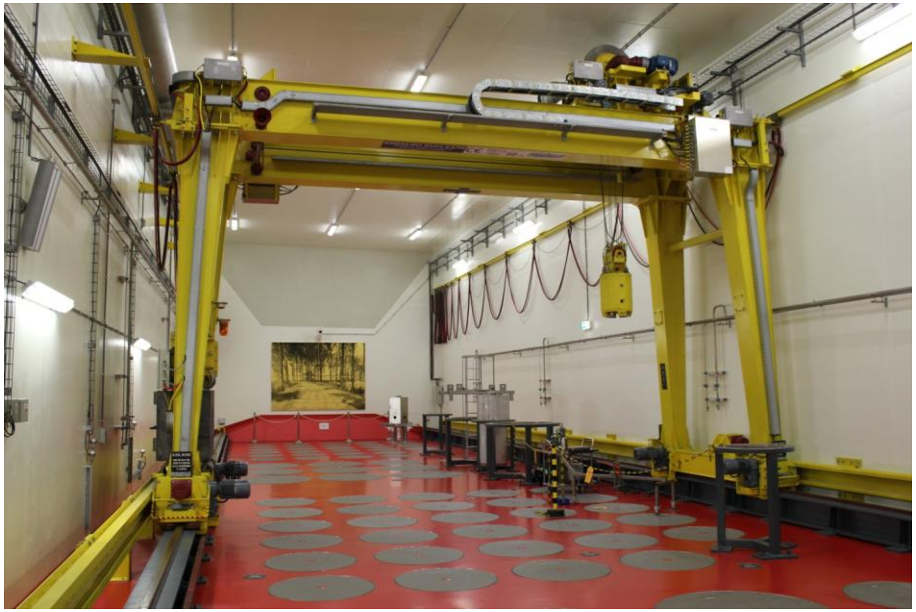
Schematic cross section through HABOG
Referring to an image by COVRA

Impressions of the HABOG at Vlissingen, NL

Reception Area

Hot Cell

Heavy shielding door



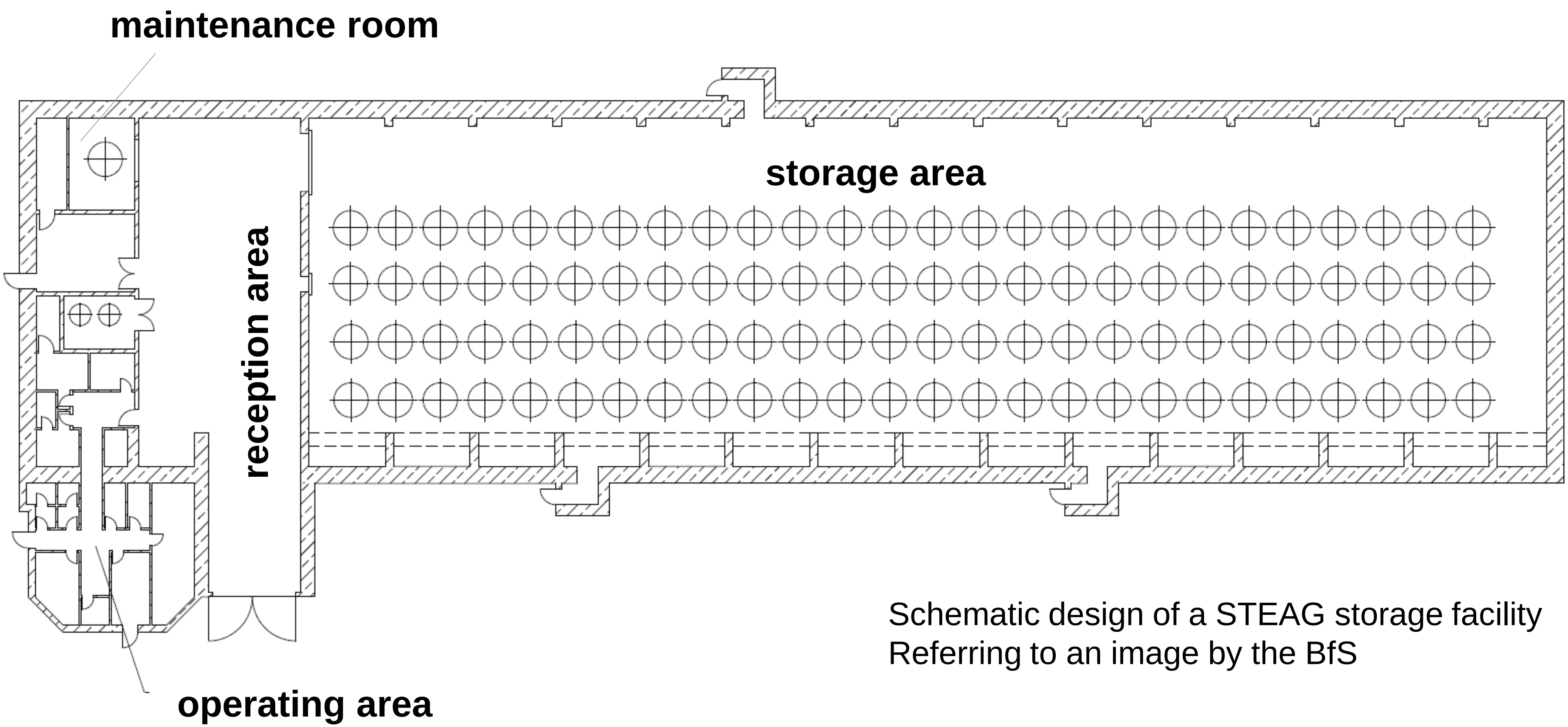
Storage module for heat-generating high level waste

STEAG-Concept at Krümmel, Germany

Operator: Vattenfall [4]

Construction: STEAG (Steinkohlen-Elektrizitäts-AG)

Schematic design of a STEAG storage facilitiy



Schematic design of a STEAG storage facility
Referring to an image by the BfS

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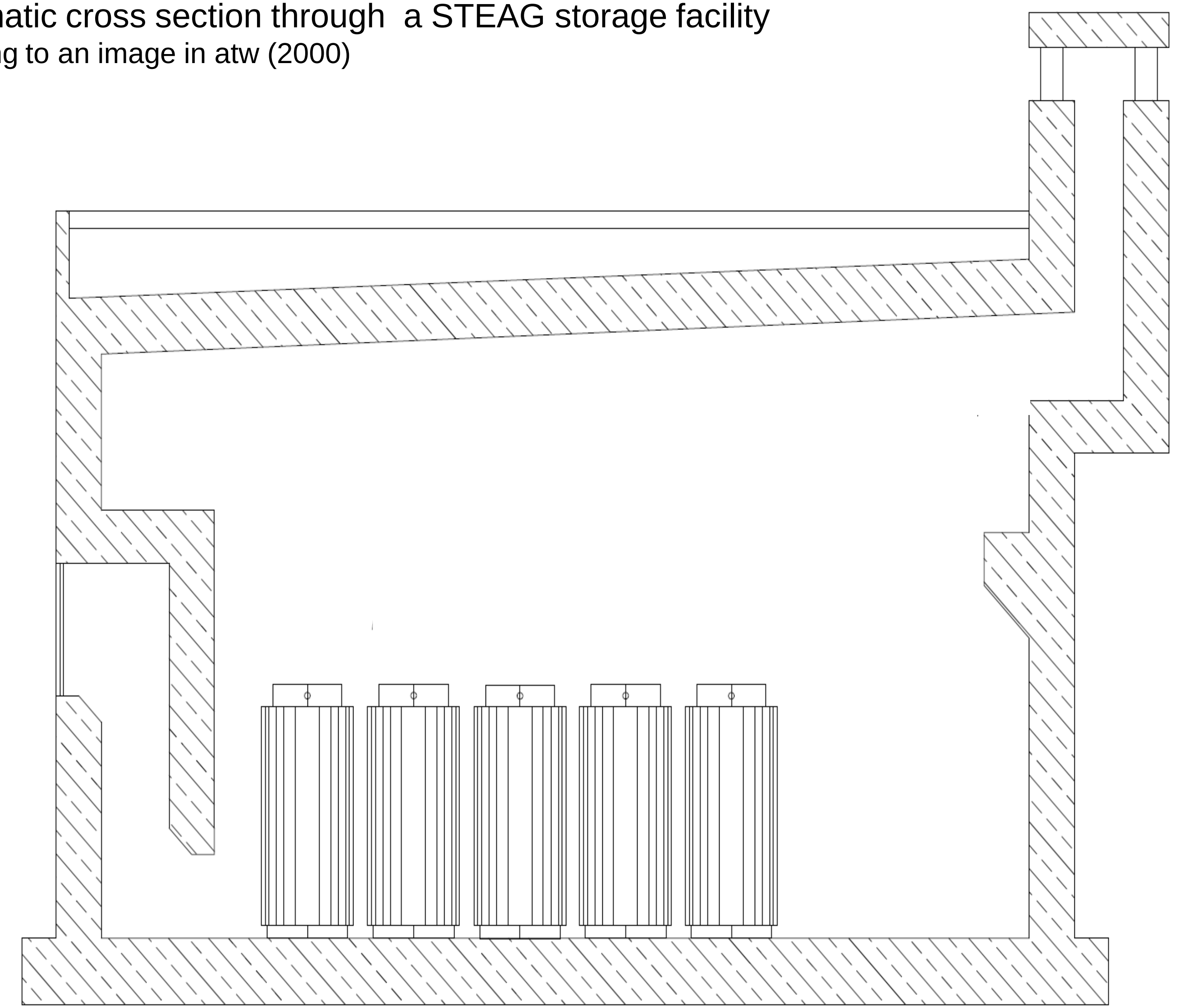
Schematic design of a STEAG storage facilitiy

Schematic cross section through a STEAG storage facility
Referring to an image in atw (2000)



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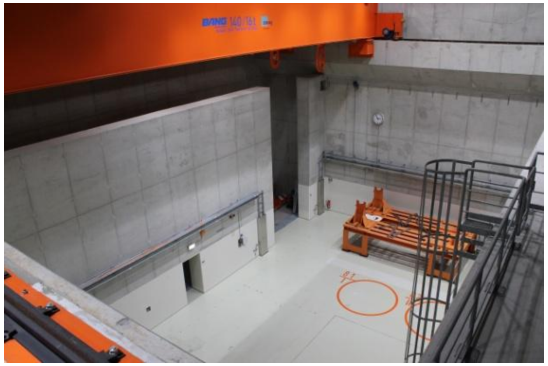
Impressions of the STEAG-facility at Krümmel



Reception area

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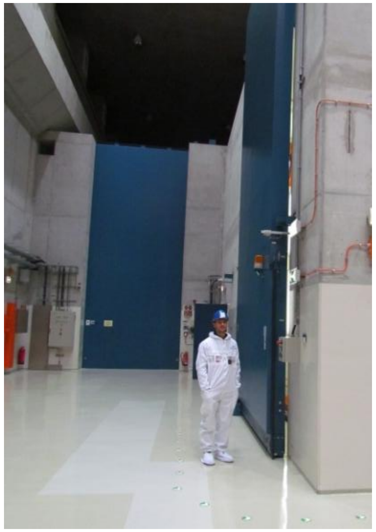


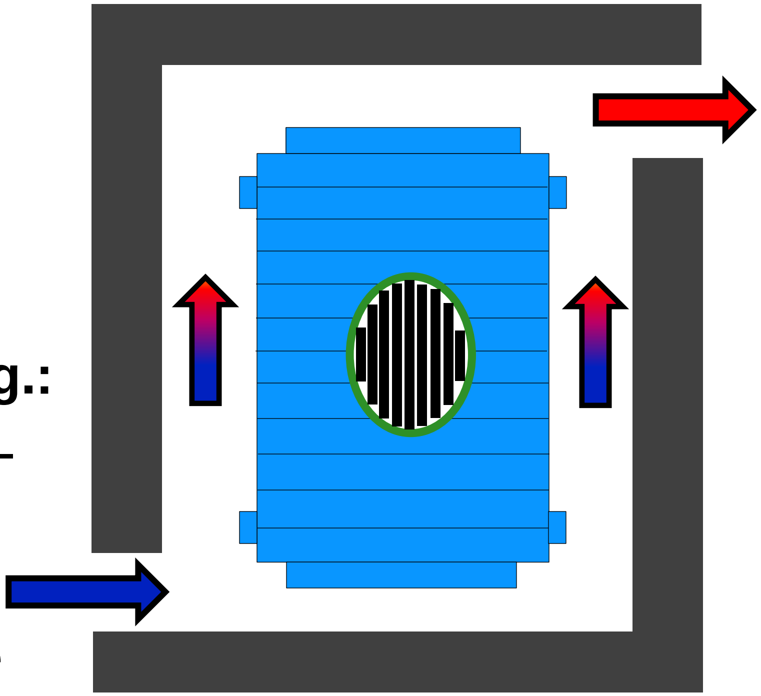
Storage area

Maintenance room

How are the safety objectives realized?

Safety objectives in general:

- Radiaton shielding
- Safe enclosure
- Removal of decay heat
- Subcriticality



Specified in (inter-)national guidelines, e.g.:

- IAEA-TECDOC-1558 - Selection of Away-From-Reactor Facilities for Spent Fuel Storage - A Guidebook
- ESK (D) - Guidelines for dry cask storage of spent fuel and heat-generating waste
- ENSI-G04/d (CH) - Design and operation of storage facilities for radioactive waste and spent fuel

IAEA-TECDOC-1558 - A Guidebook [1]

PROJECT NEEDS AND SELECTION CRITERIA FOR AFR STORAGE

Project needs:

1. Spent fuel information
2. Location and infrastructure
3. Facility needs
4. Resourcing needs
5. Regulatory needs
6. Management of project, quality and risk
7. International obligations

Selection criteria:

8. Site
9. Safety and licensing
10. Environmental impact
11. System flexibility
12. Operation and maintenance
13. Decommissioning
14. Cost and financing
15. Bid evaluation

IAEA-TECDOC-1558 - Safety and licensing [1]

Structural performance

- Ability to withstand loads and to last for the required period
- Compatible with site and environmental conditions
- Ability to withstand accident conditions
- Potential for massive collapse of structures and their impact on safety should be known

Heat removal

- Temperature limits should be established
- Adequate heat removal required

Subcriticality

- Inadvertent criticality should not be possible
- Neutron absorbing material if used should last for the life of the facility
- All credible situations affecting criticality safety should be reviewed.

Shielding

- Adequate shielding
- Appropriate measures to prevent loss of shielding
- Storage should maintain its shielding for all fuel handling activities
- Occupational and off-site doses should be acceptable

IAEA-TECDOC-1558 - Safety and licensing [1]

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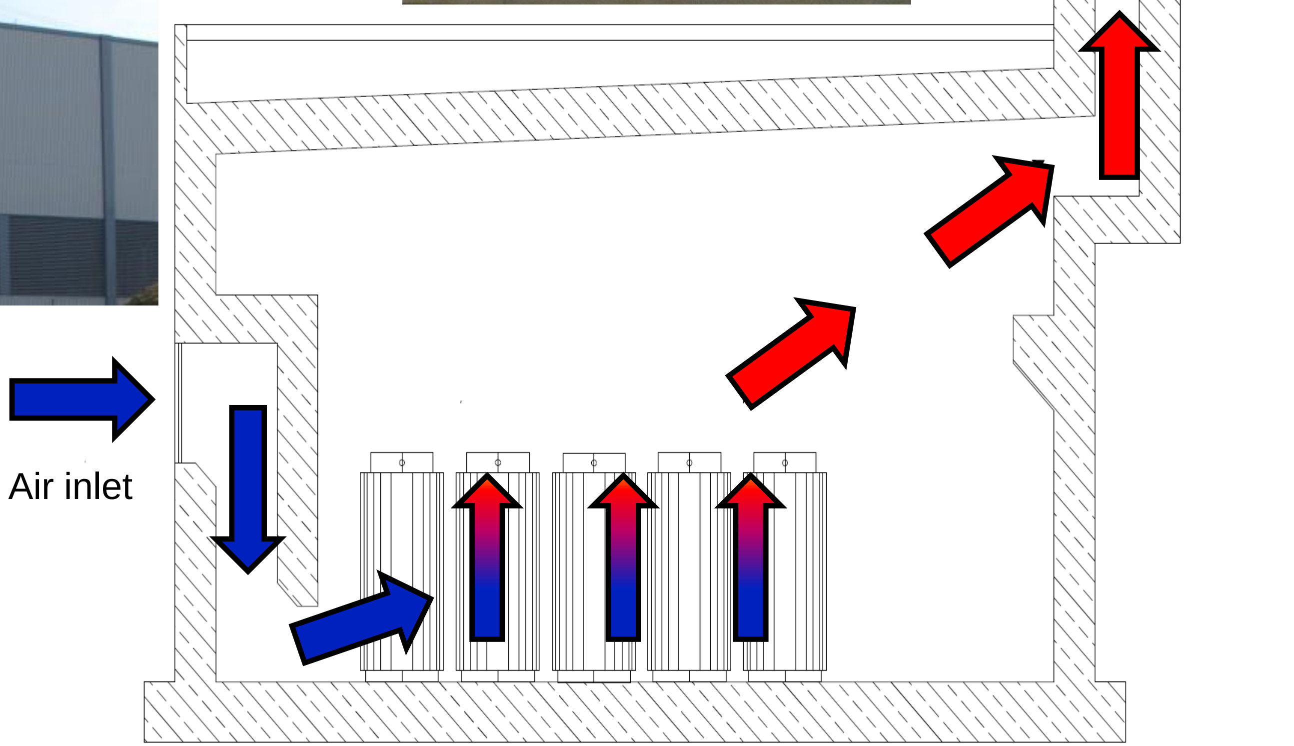
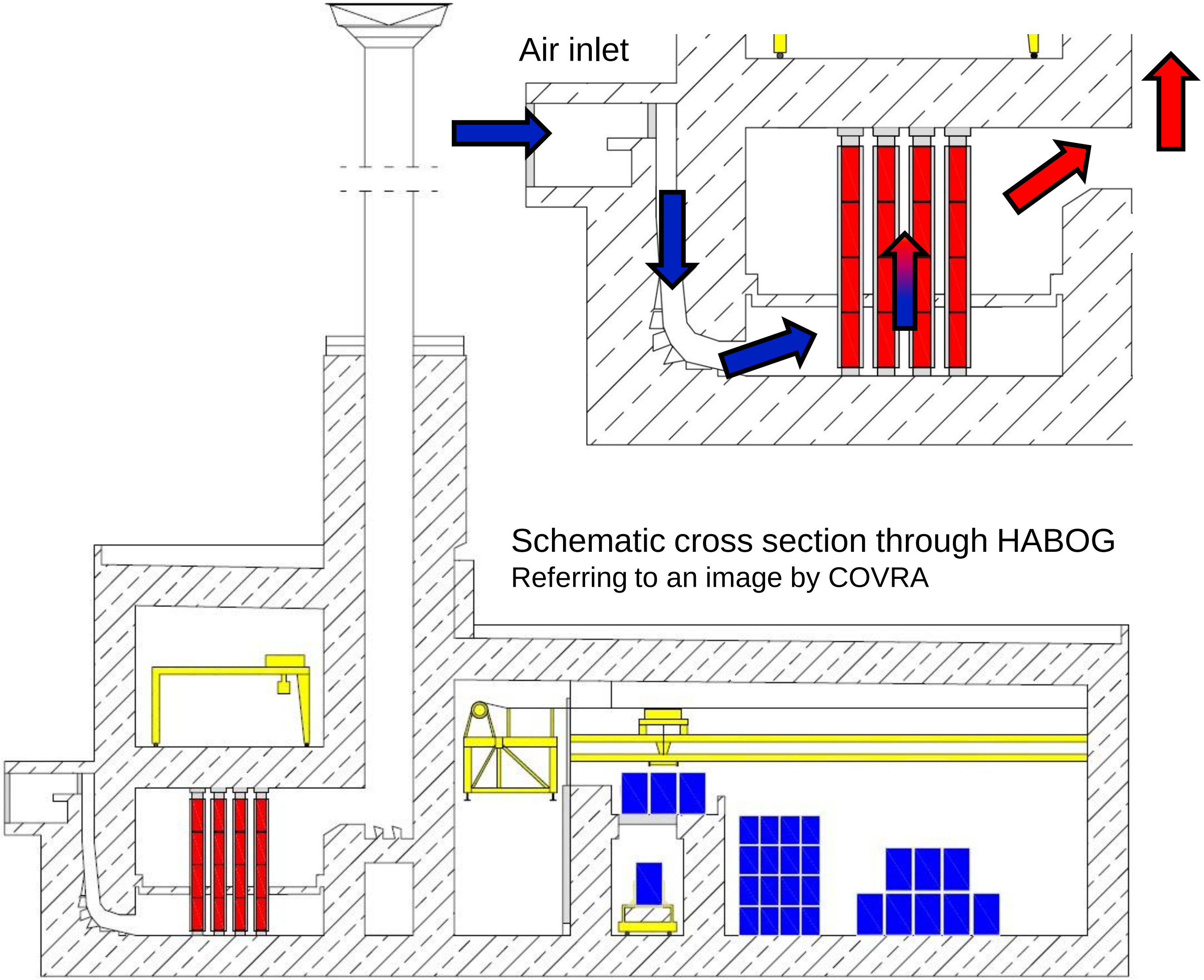


Schematic cross section through a STEAG storage facility
Referring to an image in atw (2000)

How are the safety objectives realized?
Heat removal



Schematic cross section through HABOG
Referring to an image by COVRA

IAEA-TECDOC-1558 - Safety and licensing [1]

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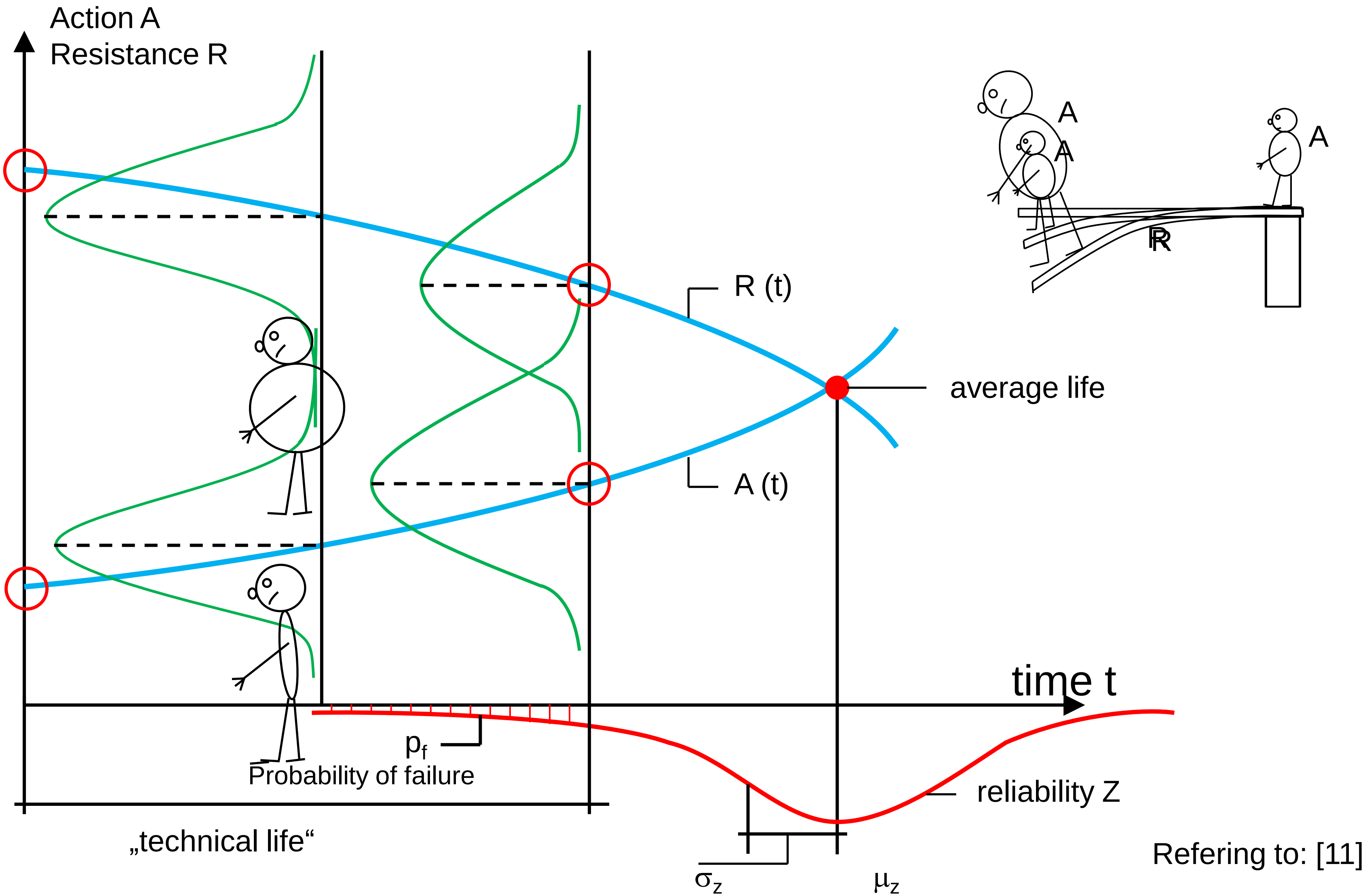
Structural performance - Action and resistance



Refering to: [11]

Scattering of material (concrete) parameters

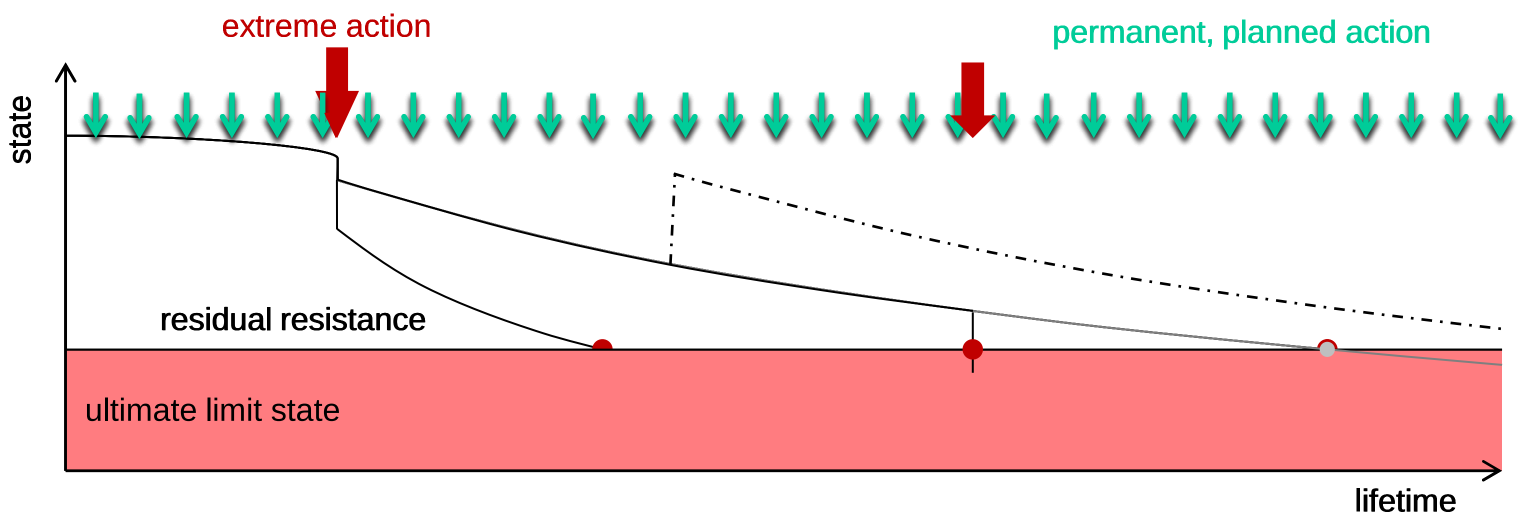
Inside concrete by Micro-CT

Why does the resistance of a structure decrease?

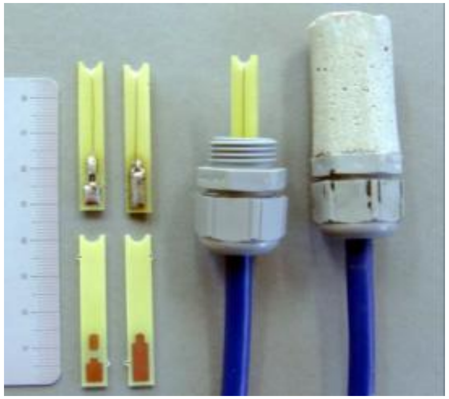
Several parameters related to:

- material
- structural details or design
- workmanship
- internal stresses
- external stresses
- in-service stresses
- level of maintenance. [10]

State-lifetime-relation of a building with respect to extreme actions



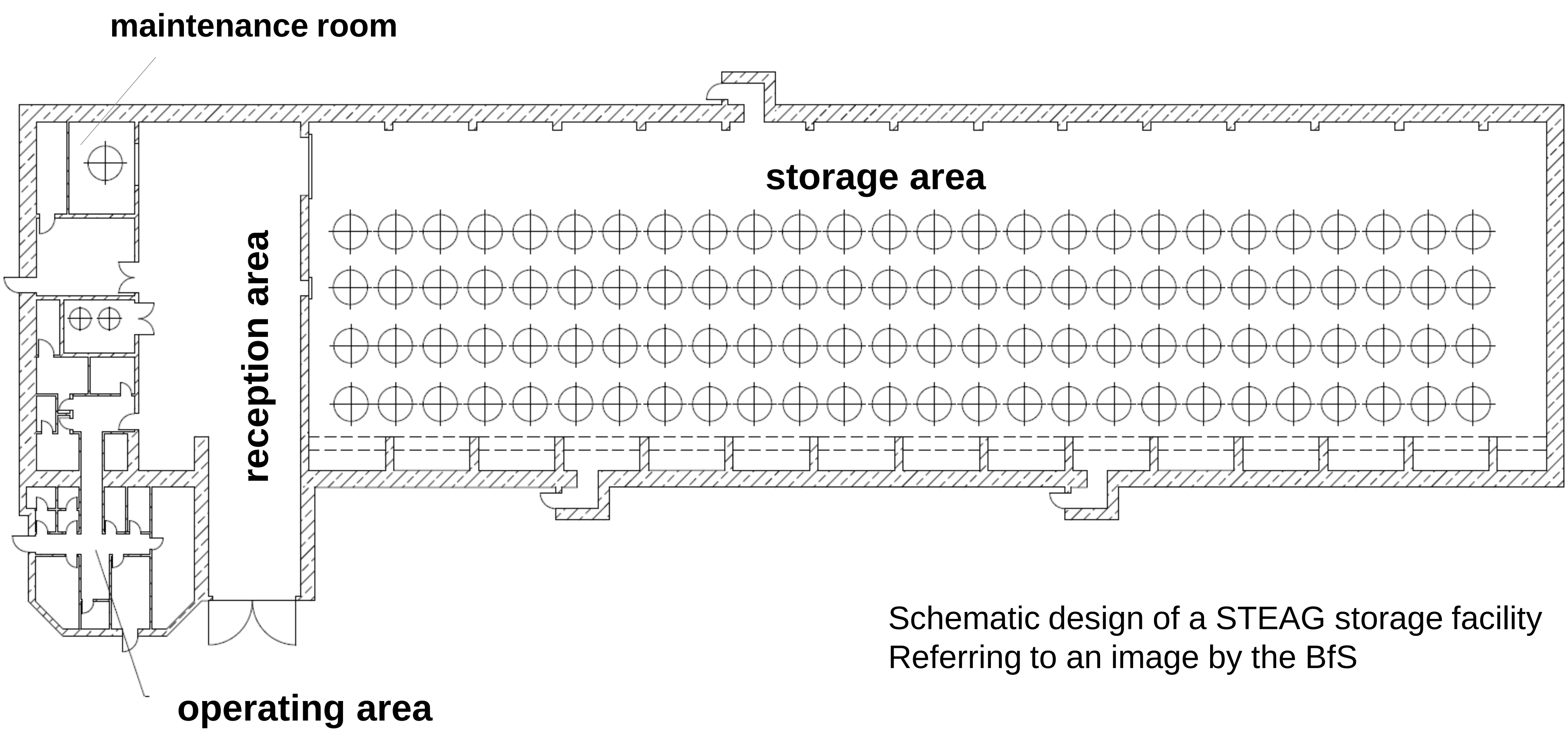
Monitoring methods



Concrete Property or Characteristic \ Evaluation Method*	Air Permeability (S)	Audio Methods (N)	Break-off Methods (S)	Carbonation Depth (D)	Chloride Testing (S)	Core Testing (D)	Infrared Thermography (N)	Instrumentation (N)	Magnetic Methods (N)	Modal Analysis (N)	Petrographic Methods (D)	Probe Penetration (S)	Pullout Testing (S)	Radar (N)	Radiation/nuclear (N)	Rebound Hammer (N)	Stress Wave Transmission (N)	Tomography (N)	Ultrasonic Pulse Velocity (N)	Visual Inspection (N)
Alkali-Carbonate Reaction											X									
Air Content	X										X									
Acidity				X	X															
Alkali-Silica Reaction											X									
Bleeding Channels											X									X
Cement Content											X									
Chemical Composition											X									X
Chloride Content					X	X														
Compressive Strength			X			X						X	X			X			X	
Concrete Cover						X			X					X						
Aggregate Content											X									
Mixing Water Content											X									
Corrosive Environment	X			X	X															X
Cracking		X				X		X			X				X		X	X	X	X
Creep						X		X												
Delamination		X				X	X				X				X		X	X	X	X
Density						X									X					
Elongation						X		X												
Embedded Parts														X	X			X		
Frost Damage											X									
Honeycomb						X					X				X			X	X	X
Modulus of Elasticity						X													X	
Modulus of Rupture						X														
Moisture Content						X					X									
Structural Performance		X						X		X										X
Permeability	X										X									
Pullout Strength													X							
Aggregate Quality											X									X
Freeze/Thaw Resistance											X									
Soundness						X									X			X		
Splitting-Tensile Strength						X														
Sulfate Resistance											X									
Tensile Strength			X			X														
Concrete Uniformity											X					X				X
Voids						X								X	X		X	X	X	X
Water-Cement Ratio											X									

[Source: 12] (N) = nondestructive method, (S) = semidestructive method, and (D) = destructive method.

Monitoring and refurbishment in the storage area?



Schematic design of a STEAG storage facility
Referring to an image by the BfS

Thank you for your attention!

- www.entria.de

- Project number 02S9082A

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References

[1] International Atomic Energy Agency: IAEA-TecDoc-1558: Selection of Away-From-Reactor Facilities for Spent Fuel Storage - A Guidebook, September 2007

[2] National Nuclear Security Administration, Office of Nonproliferation and International Security (NIS): Next Generation Safeguards Initiative. Safeguards-By-Design Facility Guidance Series (NGSI-SBD-001). Guidance for Independent Spent Fuel Dry Storage Installations. May 2012

[3] http://www.holtecinternational.com/productsandservices/wasteandfuelmanagement/hi-storm/

[4] http://www.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=NP-6940 %20%20%20%20%20%20%20%20%20%20%20&Mode=download

[5] http://reg.gsapubs.org/content/19/73/F5.large.jpg

[6] Photograph by Vattenfall

[7] Complementary Safety margin Assessment COVRA N.V. (HABOG)

[8] Statement of the Nuclear Waste Management Commission (ESK) ESK stress test for nuclear fuel cycle facilities in Germany. Part 1: Nuclear fuel supply facilities, storage facilities for spent fuel and heat-generating radioactive waste, facilities for the treatment of spent fuel

[9] http://www.ingenieur.de/Branchen/Bauwirtschaft/Deutscher-Beton-fuer-World-Trade-Center-in-New-York-haelt-Bomben-stand

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[12] Assessment and management of ageing of major nuclear power plant components important to safety: Concrete containment buildings - IAEA-TECDOC-1025, Vienna, 1998