Package Design: Aging Management – Long-term Storage and Containment

Extended Storage after Long-Term Storage

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Extended Storage after Long-Term Storage

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Outline:

- Introduction
- Spent Fuel Storage in Germany
- Aging Management and Future Needs
- Additional Material Investigations
- First experience with extending storage
- Conclusions

International situation:

Storage needs to be extended due to insufficient and/or unavailable

- **spent fuel reprocessing capacity**
- **spent fuel disposal facilities**

mainly as a consequence of the **lack of political decision** possibly driven by absence of public confidence and/or acceptance

In Germany:

in 2013 new disposal search act:

- ➔ Restart of the siting process followed up by evaluation and exploration of different options
- ➔ **Availability of the repository until ????**

Spent Fuel Storage in Germany

Wet Storage in NPP Pools

CASTOR® V cask design by GNS (source: GNS)

Since 1992 ……

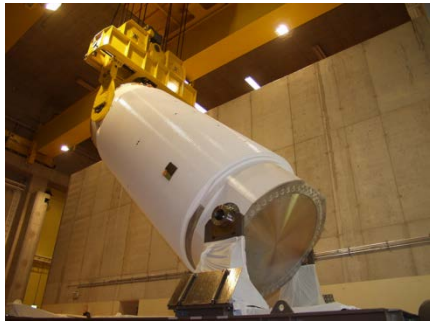
Dry Storage in Dual Purpose Casks at Centralized Interim Storage Facilities

Storage Building
+
Dual Purpose Casks

Transport Ban and Revision of Atomic Energy Act

Since 2002 …..

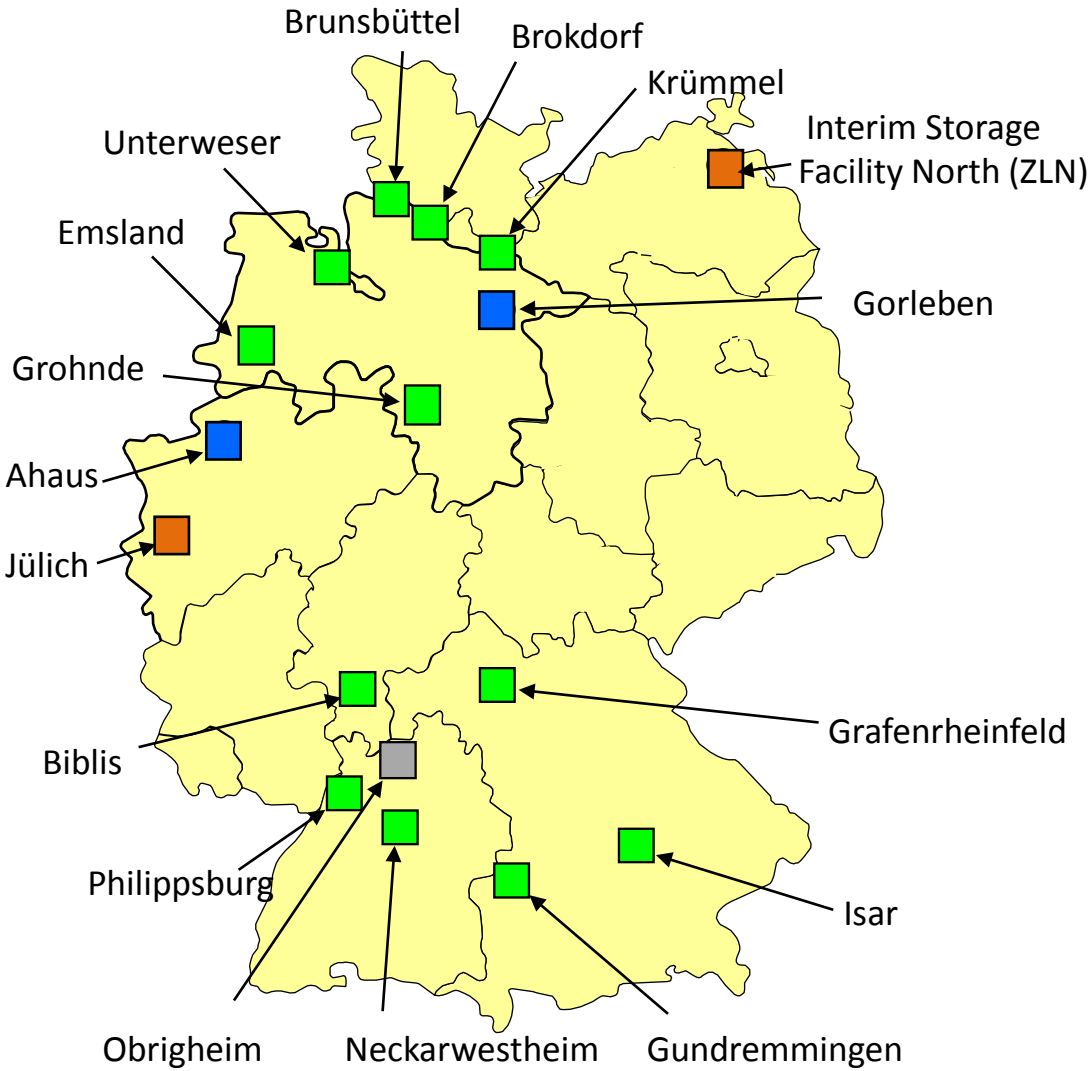
Dry Storage in Dual Purpose Casks at On-Site Interim Storage Facilities at all NPP Sites



Storage licenses limited to 40 years for administrative reasons !

Spent Fuel Storage in Germany

- on-site interim storage facility in operation
- on-site interim storage facility (applied)
- centralized interim storage facility
- local interim storage facility outside reactor sites



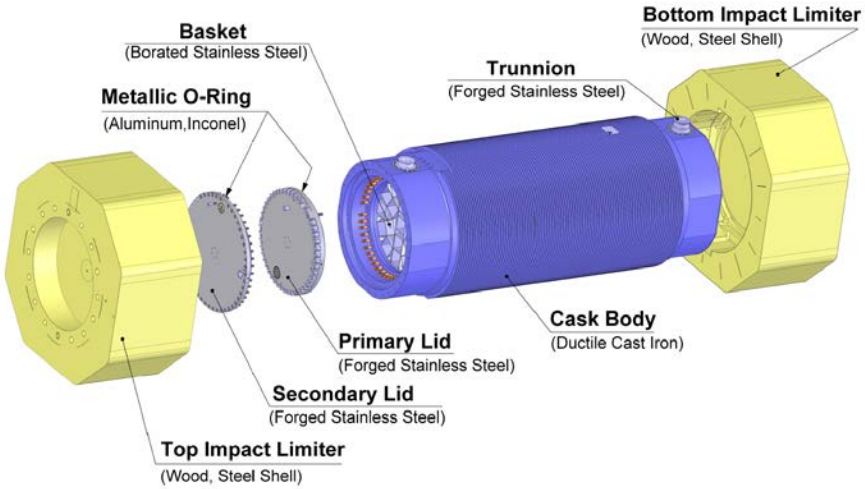
Spent Fuel Storage in Germany

The Storage Concept

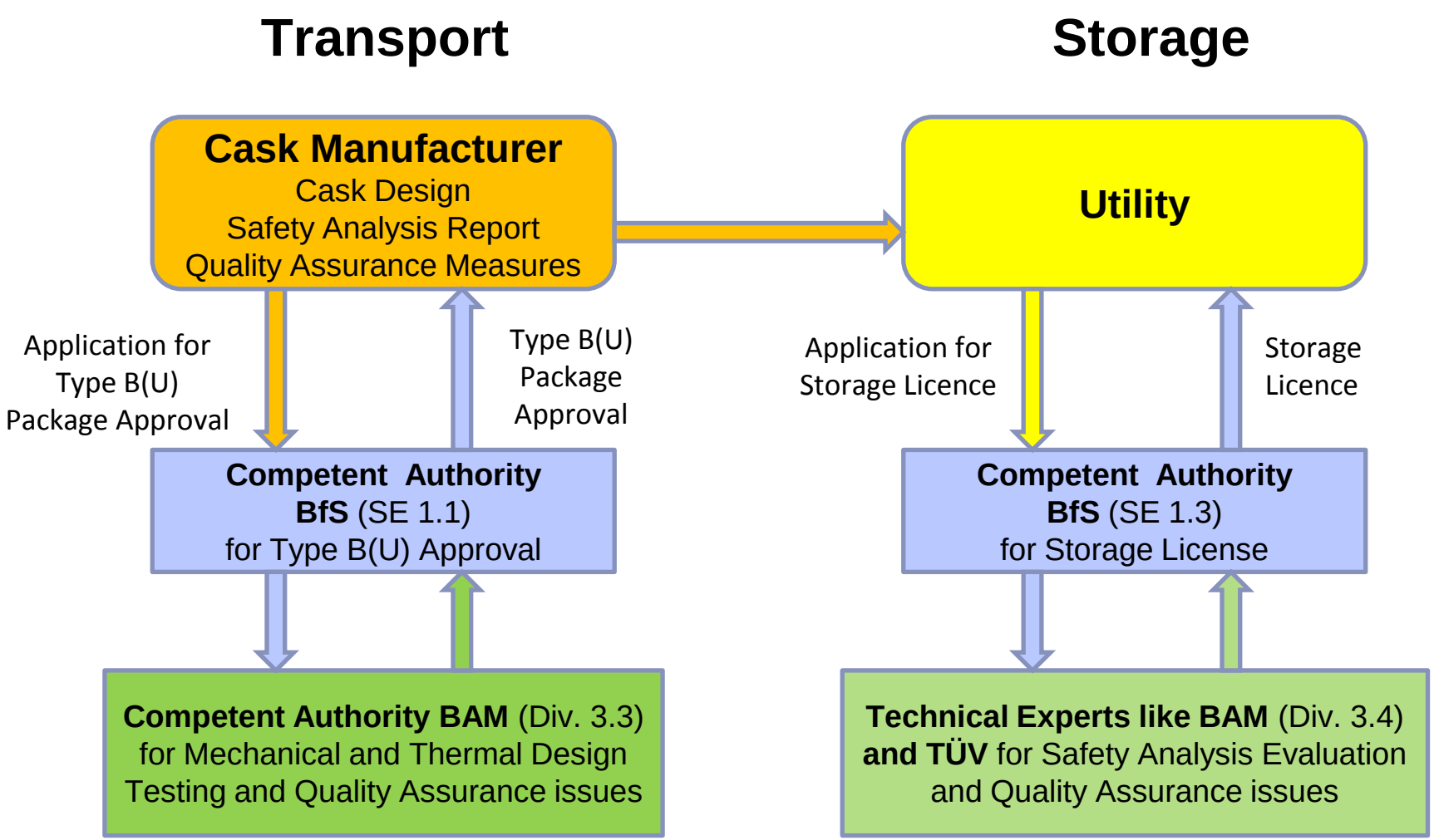
- Accident safe dual purpose metal casks with
  - Type B package design approval
  - Two independent sealed barrier lids
  - Permanent leak-tightness monitoring
  - Dried and inert cask interior
- Storage period 40 years
- Casks in a storage building for weather protection and additional shielding

Main Cask Design Criteria

- Nuclear safety (subcriticality)
- Radiation protection (shielding)
- Decay heat removal
- Site specific accident safe cask design (integrity, leak-tightness)
- 40 years cask durability



Safety Assessments - Cask Design Testing and Approval

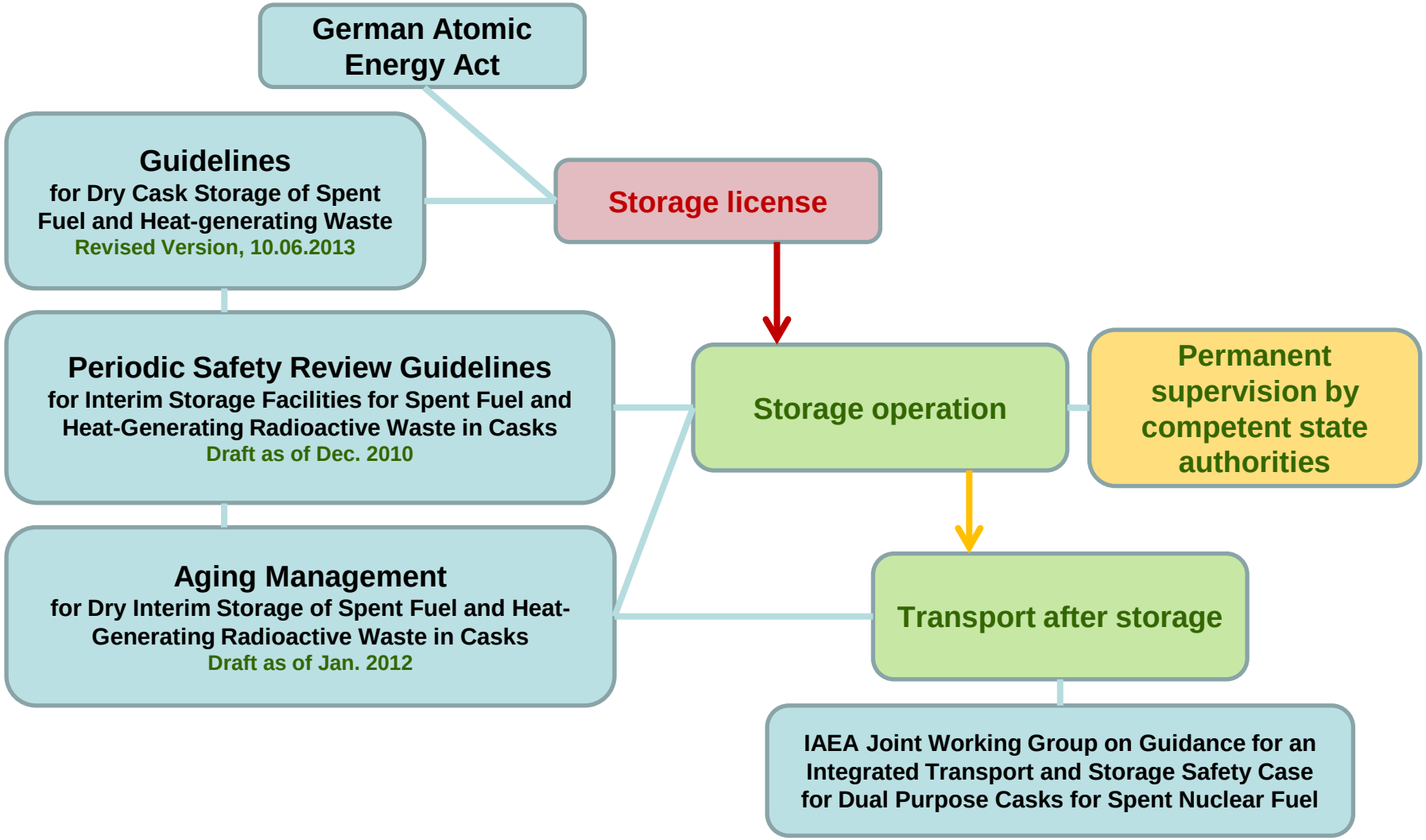


Guidelines for Dry Cask Storage of Spent Fuel and Heat-generating Waste (revised version as of 10.06.2013)

- refer to a **temporary storage** … with the aim of a **subsequent disposal**
- **since a decision on the related repository concept and its realization has not been made yet, the actual time needed for storage cannot be stated**
- **therefore:** safety requirements are formulated such that the **specific safety analyses** are performed **for each** of the **periods applied for** in the licensing procedures
- **however: period of 40 years**, on which previous storage licenses are based, may be referred to as an **appropriate time scale**
- **knowledge gained** so far on this storage period **can be taken into account**
- if this **period will not be sufficient**, **appropriate additional analyses are to be performed**

  (e.g. on the long-term behavior of materials and components of the casks and inventories under the specific load conditions of the storage facility)

Aging Management and Future Needs



Periodic Safety Review Guidelines for Interim Storage Facilities for Spent Fuel and Heat-Generating Radioactive Waste in Casks

Draft as of Dec. 2010

Main goals:

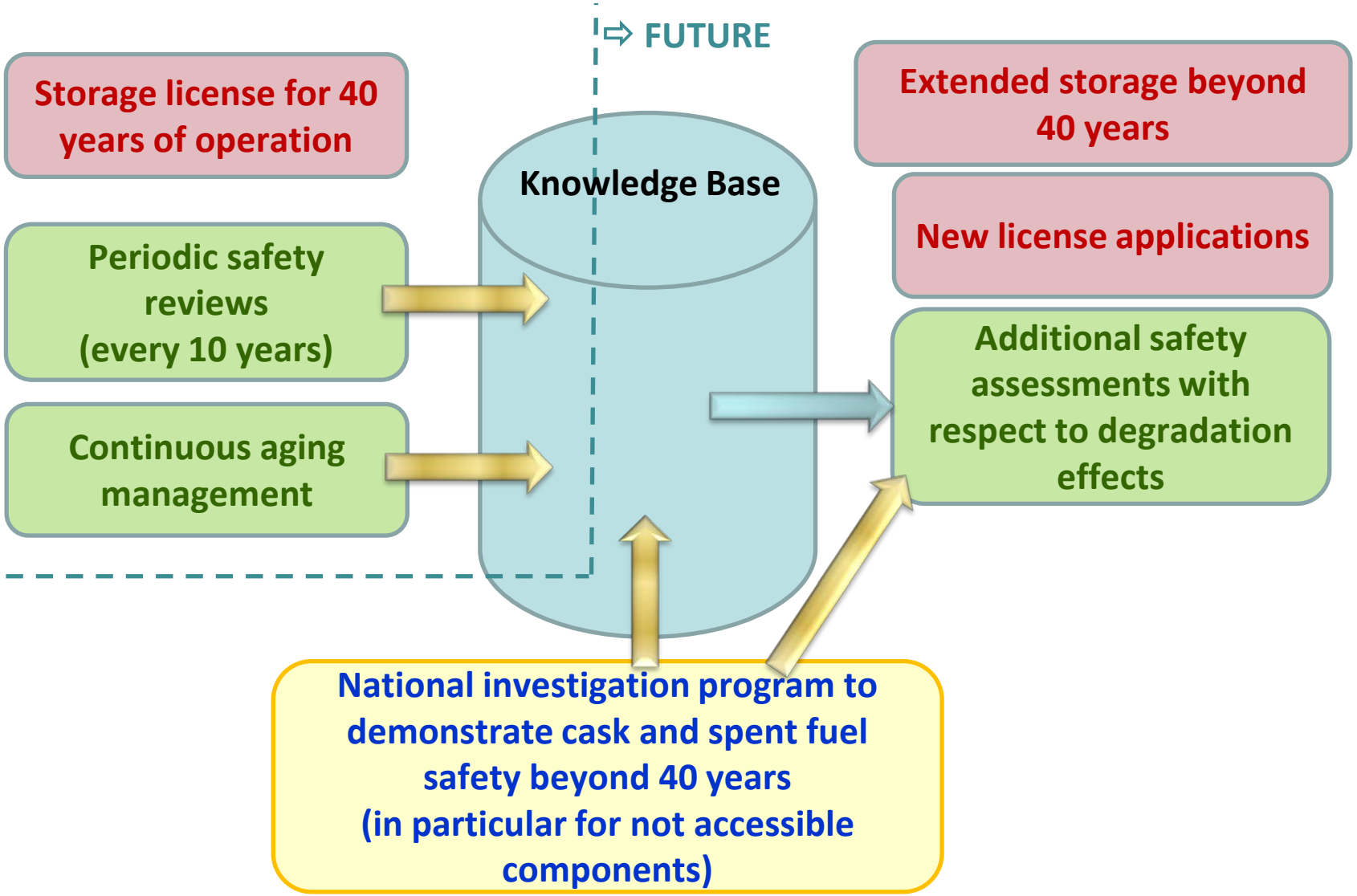
- **Documentation and evaluation of operational experience and changes with respect to the level of safety, integrity of operation and dose minimisation.**
- **Updated safety evaluation under consideration of the state-of-the-art of science and technology and with respect to:**
  - Safe and reliable continuation of operation.
  - Consequences of aging mechanisms on all relevant storage components like building structures, handling equipment, casks and cask inventories.
  - Adherence of safety requirements with respect to cask handling and transportation after storage.
- **Derivation of conclusions and provisions for further operations.**

Aging Management for Dry Interim Storage of Spent Fuel and Heat-Generating Radioactive Waste in Casks

Draft as of Jan. 2012

- **Approach to the technical aging management**
  - Planning
  - Implementation
  - Documentation
  - Assessment
- **Requirements for the monitoring concept**
  - Casks (accessible regions; not accessible regions)
  - Storage building
  - Other technical equipment (fire protection, crane, cask monitoring installations)
- **Non-technical aging**
  - Long-term personnel management
  - Long-term documentation and knowledge management
  - Long-term operation management (safety management, electronic data processing systems)

Aging Management and Future Needs



Additional Material Investigations

Driving aging forces on storage casks

- **Gamma radiation**
- **Neutron radiation**
- **Decay heat**
- **Environmental effects** (moisture, air pollution)
- **Mechanical stresses** (fuel rods, bolted lids and trunnions, metal seals)

Materials

- **Metals (ductile cast iron, various steel types, basket materials)**
- **Polymers (neutron shielding, auxiliary seals, cavity sealing)**

Aging effects

- **Degradation by irradiation**
- **Mechanical degradation (relaxation, creeping)**
- **Corrosion**

Detection and evaluation of safety relevant changes of material properties and extrapolation of long-term performance to ensure long-term safety.

Additional Material Investigations

Data gaps identified by BAM concerning safety issues for storage periods beyond 40 years:

➢ Long-term performance of bolted closure systems

- Bolt relaxation
- **Metal seal relaxation and creep**
- Material degradation by temperature, time, ambient conditions
- **Leakage rate measurements after long storage periods** concerning elastomer auxialiary seal degradation and helium contamination
- **Safety margins in case of severe accident scenarios**

➢ Degradation of polymer components for neutron shielding

➢ Reliability of pressure monitoring devices

First experience with extending storage

Extended storage license application after expiration of initial 20 years:

Jülich AVR storage facility with 152 CASTOR THTR/AVR casks

License expired June 30, 2013 !!!

Options:

- Extension of the Jülich storage license
- Transportation of all casks to the Ahaus storage facility added by an additional 20 year storage period
- Shipping of the research reactor fuel back to the U.S. for further storage and/or reprocessing

Issues arising:

- evaluation of aging effects
- selected inspections to verify e.g. leak-tightness, lid bolt pre-stress
- updated safety assessments considering the current state-of-the-art

First experience with extending storage

Realized measures concerning

- **a nearly identical cask design is already approved for 40 years storage period in the Ahaus facility**
- **radiation levels and decay heat from AVR fuel are very low**

➢ **Visual inspection regarding corrosion effects**

➢ **Inspection of selected bolts regarding plastic deformation**

- Metallographic methods
- High precision length measurements

✓ **Result: No relevant plastic deformations due to applied torques**

➢ **Leakage rate measurements at selected primary lids**

- **Challenge: Potential helium contamination of the elastomeric auxiliary seals** from the previous interim storage period
  Reason: space between primary and secondary lid is filled with helium overpressure for monitoring purposes

✓ **Result: Required leakage rate of 10^{-8} Pa m^3/s could be demonstrated in all cases but measurements needed up to 70 hours**

Conclusions

- The German concept of dry spent fuel interim storage in dual purpose casks has demonstrated its suitability for over 20 years whether centralized or on-site.
- Storage licenses are limited to 40 years for administrative but not technical reasons.
- Due to major delays of the siting and establishment of a final repository in Germany extended interim storage periods beyond 40 years are unavoidable in the future.
- National guidelines for periodic safety reviews and aging management of interim storage facilities are currently established.
- Further long-term investigations on aging mechanisms are necessary to increase knowledge for reliable and extended predictions for storage periods beyond 40 years.
- Data gaps for extended storage safety demonstrations have been identified and BAM is running test programs with regard to the bolted closure system for long-term safe enclosure and polymers for neutron shielding.
- BAM participates in international projects to share information and close data gaps.
- First experience with safety assessments after long-term storage is currently gathered in case of an expiring 20 years storage license.