The relationship between the regulatory frameworks and codes & standards for fusion facilities

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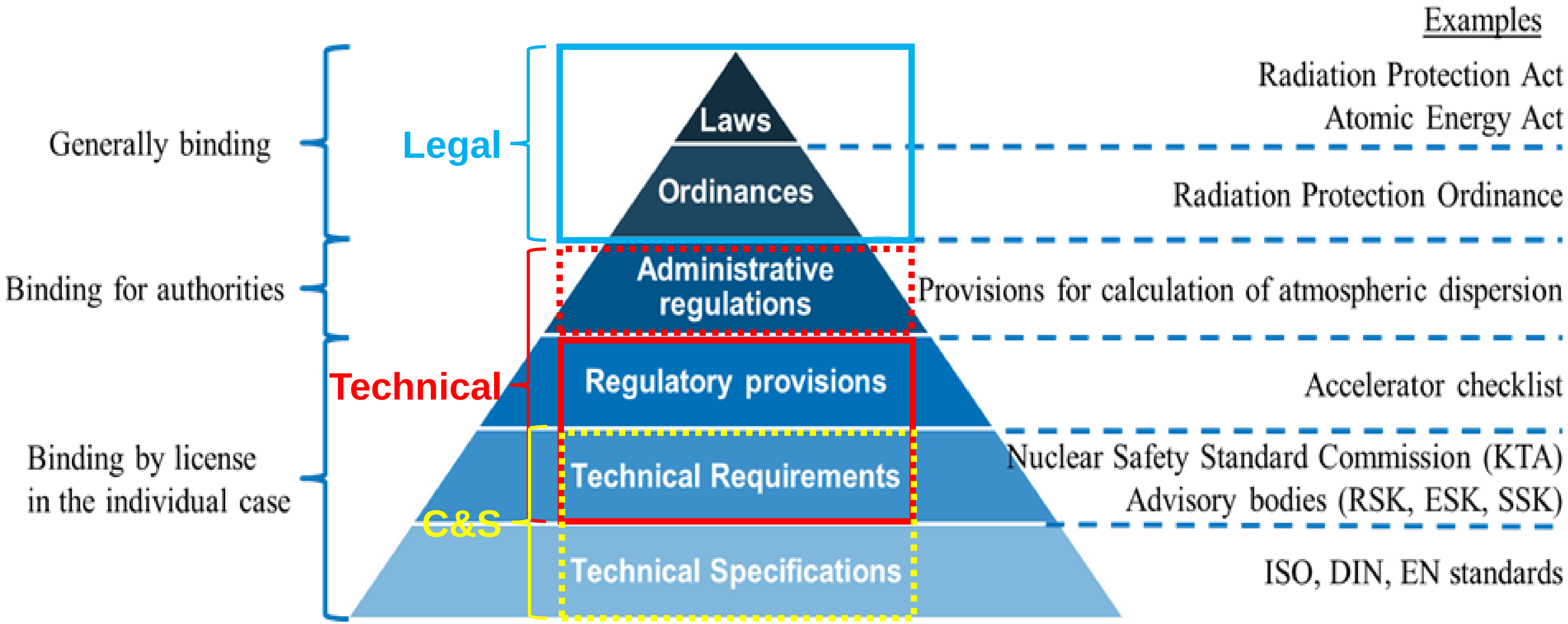
ReFus (regulation of fusion facilities)

- Launched by the German Federal Ministry of Education and Research (now Research, Technology and Space) January 2025
- Aims
  - **Analyze status quo** and **possible gaps** in the existing German legal framework and the technical regulatory requirements for fusion facilities and future fusion power plants
  - Can some of the existing **legal** framework be adopted for fusion?
  - Is a special fusion **legal** framework necessary?

  Develop concept for the legal regulation

  - Based on the specifics of fusion facilities, develop a concept for the **technical** regulation
- Project partners: three German **TSOs**, two **research organizations**, supported by nine **startups/industrial companies** as associated partners.
- Strive for a consensus by all parties if possible. If different opinions remain, they will be documented.

Hierarchy of legal, technical regulation and C&S



Concepts for legal framework for fusion facilities

- Based on the **existing Radiation Protection Act**
  - Definition of fusion facilities/clarification that they are already covered as plasma facilities/production of ionizing radiation
  - Requirements for construction/operation/decommissioning(?) licenses
  - Interaction between different licensing requirements (e. g. environmental impact assessment, construction law, …)?
- **Lessons Learned from Atomic Energy Act**
- Development of a **possible future Fusion Act**
  - One-stop-shop for licensing (“concentration effect”)?
  - Topics to cover in the act?

Status Quo in Germany: Legal basis for technical regulation

- Prevention of unnecessary exposure and dose reduction: … take note of the **scientific and technical state-of-the-art** (Section 8 of the Radiation Protection Act)
- **Normal operation**
  - **Limits for members of the public exposure** (Section 80 of Radiation Protection Act and Section 99 of Radiation Protection Ordinance)
  - **Limits for occupationally-exposed persons** (Section 78 of Radiation Protection Act)
- **Hazardous incidents**
  - **Limits for the dose in the surrounding** (Sections 104 and 194 of Radiation Protection Ordinance)
- **Thresholds** for each nuclide that require
  - **limiting exposure due to hazardous incidents**
  - **preparatory measures for emergencies or hazardous incidents**

  e.g. 28 g of H-3 (Sections 104 and 106 of Radiation Protection Ordinance)

Status Quo in Germany: Requirement for limiting exposure due to hazardous incidents

The **radiation protection executive** shall ensure that, in the planning of facilities … **structural or technical protection measures** are taken which take into account the **potential magnitude of damage** in order **to limit exposure from hazardous incidents due to the discharge of radioactive substances into the surrounding area**. The **authorizing authority** shall define the **type and scope of the protective measures** in **consideration of the individual case**, in particular of the **potential risk** associated with the facility and the **probability of the occurrence of a hazardous incident**.

… the **Federal Government** shall issue **general administrative provisions** in which **protective goals** are determined **for the prevention of hazardous incidents** … These shall take into account the **likelihood of the occurrence** of the **magnitude of damage** and, …, the **multiple of the exemption levels for unsealed and enclosed radioactive substances**.

Graded approach

- IAEA Fundamental Safety Principles (SF-1):

  3.15. Safety has to be assessed for all facilities and activities, consistent with a **graded approach**.

- IAEA General Safety Requirements (GSR Part 4 (Rev. 1)):

  Requirement 1: Graded approach to safety assessment

  A **graded approach** shall be used in determining the **scope and level of detail of the safety assessment** carried out at a particular stage for **any particular facility or activity**, consistent with the **magnitude of the possible radiation risks** arising from the facility or activity.

⇨ Compare **magnitude of the possible radiation risks** of fusion facilities with other facilities/activities causing radiations risks

⇨ Graded approach **within fusion regulation** (experiments/demonstration facilities/fusion power plants)

Radiation risks of fusion facilities

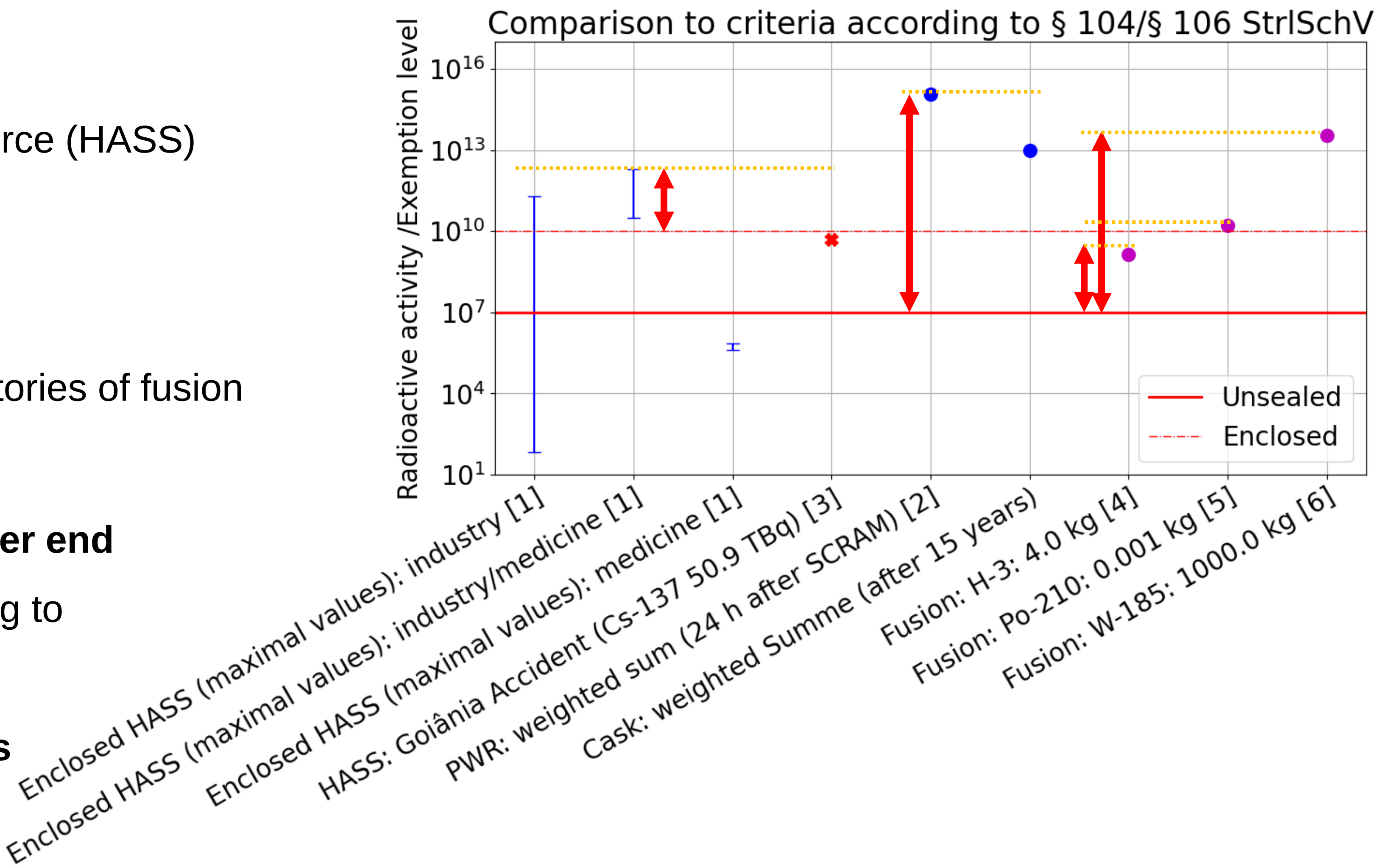
- **Inventory of fusion facilities** depending on specific fusion technology
  - Tritium
  - Activated structural materials
  - Activated corrosion products
  - Activated and tritiated in-vessel dust
- **Ionizing radiation**
- **Hazards/energies** to mobilize/endanger confinements/release radioactive inventory depending on specific fusion technology
  - Plasma (unburned fuel)
  - Magnets
  - Escalation of events (hydrogen production, explosion and fire)
  - Decay heat in structures
  - …

Comparison of radiation risks of fusion facilities with other facilities

Comparison of

- High-Activity Sealed Radioactive Source (HASS)
- PWR (24 h after SCRAM)
- Dry storage cask (15 years)
- Literature values of radioactive inventories of fusion demonstration facilities/power plants

⇨ **Fusion power plants** are at **the upper end or above facilities** licensed according to radiation protection regulation, **but well below fission power plants**



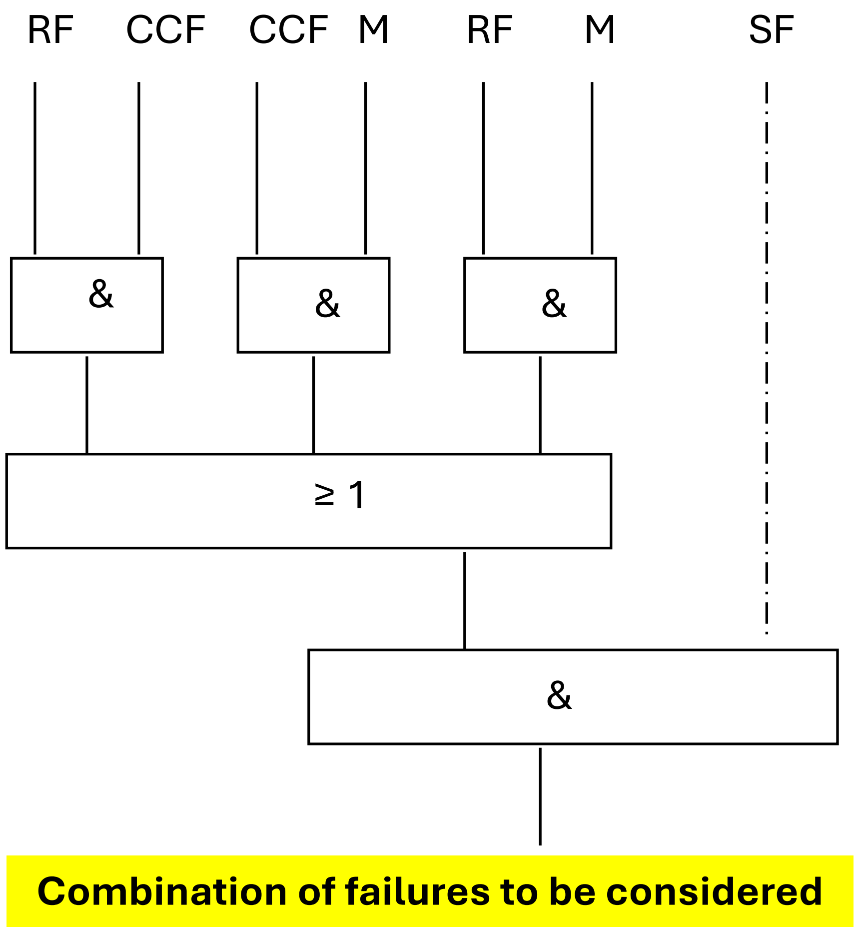
Example from nuclear regulation: German Safety Requirements for NPPs & KTA

- German **Safety Requirements for NPPs** developed between 2003 and 2012, latest update 2022
  - Developed by TSOs, German state authorities and the federal authority
  - Safety concept
  - General and specific technical requirements
  - Postulated operating conditions and events
  - Requirements for the safety demonstration
  - Requirements for the operating rules
  - Requirements for the documentation
- The **Nuclear Safety Standards Commission (KTA)** has the task to issue **nuclear safety standards** … where a **consensus** is apparent between **experts** of the **manufacturers** and the **operators** of nuclear power plants, of **authorized experts** and **state officials** and to support their application.
  - ~ 90 standards published
  - ~ 10 standards are no longer part of the revision process

Example: Instrumentation and control

- **Safety Requirements for NPPs** define
  - 13 general requirements, e.g. single failure concept
  - 11 requirements for instrumentation and control

- **KTA 3501 (Reactor Protection System and Monitoring Equipment of the Safety System)** is central standard for safety important I&C systems of the nuclear power plants
  - Detailed requirements, e.g.
    failure combinations to be handled by the I&C systems (Common cause failure (CCF), Random failure (RF), Maintenance (M), secondary (consequential) failure (SF))



Examples of requirements from already existing fusion related C&S

ISO 16646:2024 Fusion installations — Criteria for the design and operation of confinement and ventilation systems of tritium fusion facilities and fusion fuel handling facilities

- Requirements on different levels, e.g. :
  - Number of confinements
  - Safety concept (defense in depth) and number/definition of levels of defense (“DEC”)
  - Internal and external events
  - Deterministic and probabilistic risk assessment
  - Detailed requirements, e.g. fire protection

ISO/FDIS 18518 Magnetic fusion facilities — Requirements for the safety systems raised by the application of the superconducting technology

- Requirements, e.g.:
  - Nuclear shielding evaluation
  - Application of single failure criterion

Conclusions and outlook

- Currently, in most countries **no fusion specific technical regulation exist**
- International standards (e. g. ISO) **can define/update the scientific and technical state of the art**
- International standards might/likely will be **used by authorities/TSOs during the licensing process**

$\Rightarrow$ **International standards can become de facto technical regulation requirements**

$\Rightarrow$ **Applicability/scope** of standards should clearly be defined (e.g. specific fusion technology)

$\Rightarrow$ **Graded approach** should be considered when creating standards (with appropriate criteria)

$\Rightarrow$ **Interrelation** with legal and technical **regulation needs to be considered**

Thank you very much

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