Towards a Fusion Specific Regulatory Framework Based on the Applicability of the Current Nuclear Framework

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Motivation

Different fusion projects using tritium are in the design, planning or building phase

They contain a significant amount of radioactive inventory, so they will fall under safety regulation

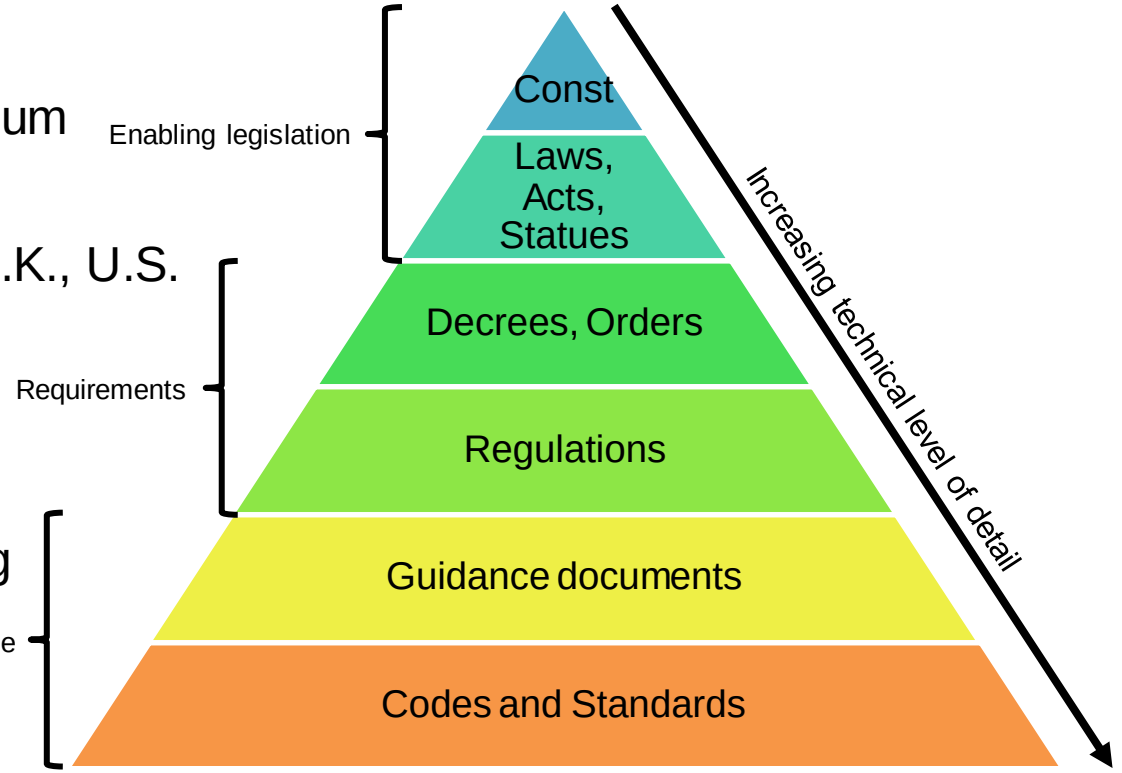
Therefore:

- Assess the existing international approaches for fusion regulation
- Determine, which parts of the existing nuclear framework can/must be used
  - IAEA
  - European directives and regulations
- Define requirements for a fusion specific regulatory framework
- If the future fusion regulation should be based on the existing nuclear regulation

⇒ **Derive recommendations for the implementation of a legal and regulatory framework**

Existing International Approaches for Fusion Regulation

- At present, no country was found that has a **dedicated comprehensive fusion-specific regulatory framework** for the whole **lifecycle** from **siting** to **decommissioning**
- Safety requirements applied to fusion are based primarily on **experience** with **fission**
- **Regulation hierarchy pyramid** used
- **France** and **U.K. currently regulate** fusion facilities using tritium (U.S. in the past)
- **Ongoing activities** on fusion regulation e. g. China, Korea, U.K., U.S.
- Internationally, differences in the **definition** of "**nuclear facilities**" (use of fissile materials?)
- **Regulation** of **radiation facilities** and **radiation protection** is applicable to fusion facilities and form the basis for licensing
- Fusion facilities **"fall into gap"** between **regulation for radiation facilities** and **fission power plants** with respect to their **radiological hazard potential**



Graded Approach

- **Aim:** To balance stringency of regulation with radiological hazard potential of the facility
  - Regulations, licensing, oversight, etc.

- **Thermal power** of reactors/research reactors is used as metric
  - For fission reactors the thermal power is an **approximate measure** for the **radioactive inventory** and therefore for a **potential source term** in the case of severe accidents
  - If applied to fusion facilities, fusion facilities are not given benefits due to **less radio-toxic inventory** compared to fission facility (at the same power)

⇒ **So, the original purpose of using the thermal power as measure is lost**

Prescriptive versus Goal-Oriented Approach

Prescriptive approach
(e. g. Germany, Korea, China and the U.S.**)**

- Regulation contains **explicit requirements**
- **Requirements** are based on the **technology** used for the facilities the regulation is foreseen to be applied to
- **Level of detail** can go down to specific safety systems
- For new technologies: **Regulation** must be developed **first**, **requires deep knowledge** of the **technology**, needs to **follow** the **development** of the **technology**

Goal-oriented
(e. g. France, U.K.)

- Regulation sets **safety goals**, e.g. the containment of the radioactive inventory
- The **licensee** has **to prove** to the authorities that the chosen design and way to operate **fulfil the given goals**
- **Technology neutral**
- Applications require **intense and deep technical review** by the authorities
- Bears the **risk** for the licensee that the **authority** might **not accept safety claims**
- In practice, this usually leads to a **hybrid solution**, **including** some **prescriptive elements** to emphasize certain safety aspects

Safety Requirements Specifically Needed for Fusion Facilities (1/2)

Main differences between fusion and fission facilities

- Different radioactive inventories
- Distribution of inventories inside the facility
- Radiological consequences of potential releases
- Amount of operational experience
- Postulated accidents, accident analyses
- Confinement strategies
- Radioactive waste management

Safety Requirements Specifically Needed for Fusion Facilities (2/2)

Assessment of specific safety issues for fusion systems, structures, and components (SSC)

- Sources for energy release
- Types of ionizing radiations
- Activated materials
- Non-radiological hazards
- Occupational safety issues
- Mobilizable source terms transported to potential environmental release during off-normal event
- Long-lived radionuclides

Screening and Categorization of Existing Supra-National Regulations (1/4)

European Directives

- Do not address fusion specific requirements but place requirements generally applicable to all facilities
- Are mandatory for all EU Member States and must be transposed into national laws

European Basic Safety Standards Directive 2013/59/Euratom of 5 December 2012

- Uniform basic safety standards for protection of the health of individuals subject to occupational, medical, and public exposures against the dangers arising from exposure to ionising radiation
- Defines requirements for e.g. the legal system, justification, and regulatory control

Council Directive 2009/71/Euratom amended by Directive 2014/87/Euratom of July 2014

- Regulatory framework for the nuclear safety of civilian nuclear installation (formally not applicable to fusion facilities)
- General requirements of this directive could be applied to fusion facilities

Screening and Categorization of Existing Supra-National Regulations (2/4)

Council Directive 2011/70/EURATOM of 19 July 2011

- Framework for the responsible and safe management of spent fuel and radioactive waste
- Directly applicable to fusion facilities producing radioactive waste through activation processes

Commission Regulation (Euratom) No 302/2005 of 8 February 2005

- Application of Euratom safeguards to fissile materials (therefore, not to fusion facilities)
- Might need to be extended to fusion facilities as those are expected to have large tritium inventories

Non-nuclear Council Directives related to non-radioactive hazards

- Provision of general rules and requirements not specific to certain facilities
- e. g. Workers exposure to Chemical Agents (98/24/EC), Workers exposure to Carcinogens or Mutagens (2004/37/EC), Worker exposure to electromagnetic fields (2013/35/EU), Substances in electrical and electronic equipment (2011/65/EU)

Screening and Categorization of Existing Supra-National Regulations (3/4)

IAEA Safety Standards and Guides

- No dedicated IAEA safety standards for fusion facilities

IAEA Safety Standard Series No. SF-1 “Fundamental Safety Principles”

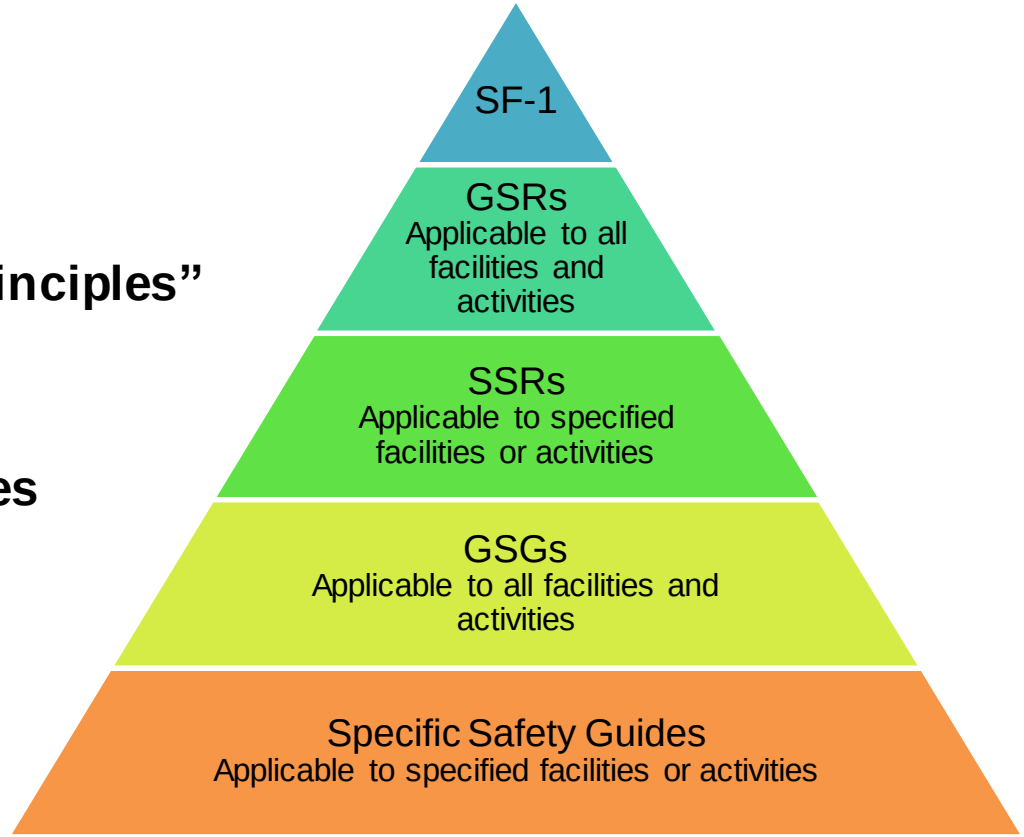
- Establish the **fundamental safety objective** and **ten safety principles** as well as their intent and purpose
- Due to the generic nature, it is **fully applicable** to **fusion facilities**

General Safety Requirements

- Most are directly applicable due to their high level of abstraction and their general requirements

Specific Safety Requirements

- Could be applied in principle



Screening and Categorization of Existing Supra-National Regulations (4/4)

General and Specific Safety Guides

- More than 70 IAEA safety guides were screened (site evaluation, design, construction and commissioning, operation, decommissioning and waste management, radiation protection, leadership and management, and safety assessment)
- Most were found to be applicable in principle
- Their application should be in a proportionate and targeted manner

Recommendations for a Fusion Specific Legal and Regulatory Framework (1/4)

Requirements can be **directly derived** from the principles of the **IAEA SF-1** and the **General Safety Requirements Part 1**

Use Council Directive 2009/71/Euratom as basis for legal framework

- Defining the competent regulatory authority
- Establishing a licensing procedure and a system for operational experience feedback
- Requiring initial assessment of safety and regular reassessment of safety
- Defining a high-level safety objective and its implementation as high level requirements
- Establishing an adequate on-site emergency organization
- Currently fusion is out of scope of this Directive

⇒ **Discuss how similar requirements could be established for fusion facilities**

Recommendations for a Fusion Specific Legal and Regulatory Framework (2/4)

For **regulatory framework** follow the **IAEA General Safety Requirements** for topics

- Siting
- Leadership and management
- Safety assessment
- Decommissioning

with fusion specific adoptions such as the postulated initiating events to be considered

Recommendations for a Fusion Specific Legal and Regulatory Framework (3/4)

Safety concept for fusion facilities is proposed (see referenced report):

- Safety objectives, derived from European Directives and the IAEA safety requirements including fundamental and supporting safety functions
- Establishment and implementation of a defense in depth concept
- Concept of multi-level confinement of the radioactive inventory
- Protection against internal and external hazards
- Establishment of a graded approach for regulation
- System for operating experience feedback
- How to address the aspects of various energy sources, radioactive inventory, and safety relevant SSCs

Recommendations for a Fusion Specific Legal and Regulatory Framework (3/4)

Develop **international harmonized codes and standards** in a consistent way

- Need to comply with high level safety requirements
- Do not create contradictions to the legal and regulatory framework

Interface between **safety**, **security** and **safeguards** for the whole lifetime of a facility

- based on IAEA safety requirements and other IAEA and WENRA documents

Action plan

- Guide the development and implementation of legal and regulatory framework
- Different steps involving different stakeholders
  - European Commission
  - Member States
  - IAEA
  - National regulatory authorities
  - Research organizations
  - Fusion industry/vendors
  - Operators
  - Technical safety organizations
  - OECD/NEA
  - Standardization organizations (ISO, EC, ASME, IEEE, etc.)

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European Commission, Directorate-General for Energy,
Study on the applicability of the regulatory framework for nuclear facilities to fusion facilities : towards a specific regulatory framework for fusion facilities *: final report*, 2022,
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