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

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2022-06-08

Technical Meeting on Synergies Between Nuclear Fusion Technology Developments and Advanced Nuclear Fission Technologies, IAEA, Vienna, Austria

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

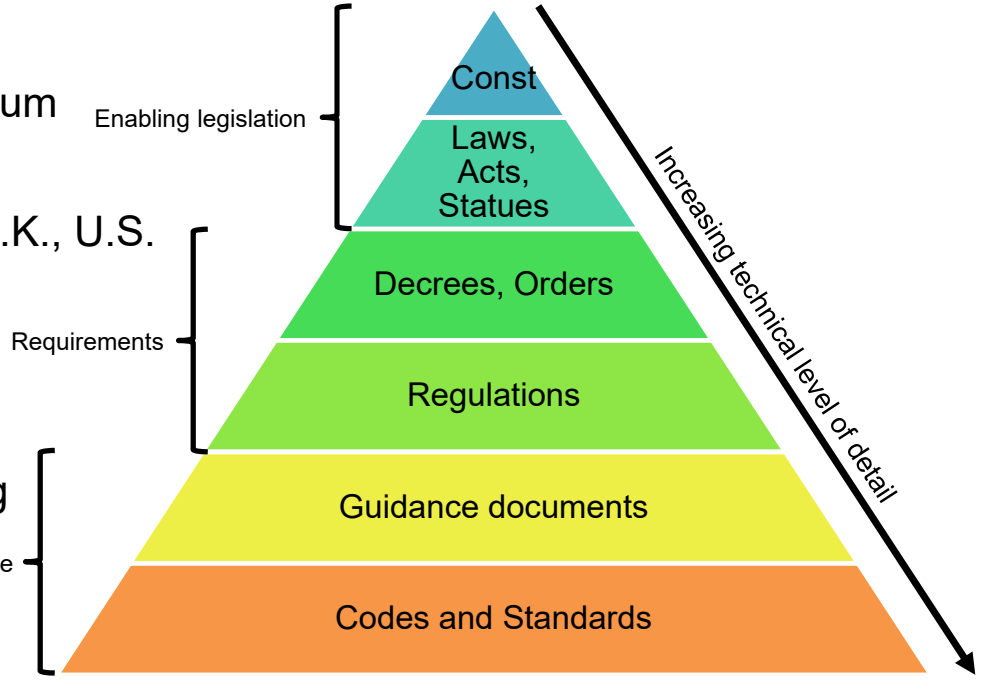
Therefore:

- 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”

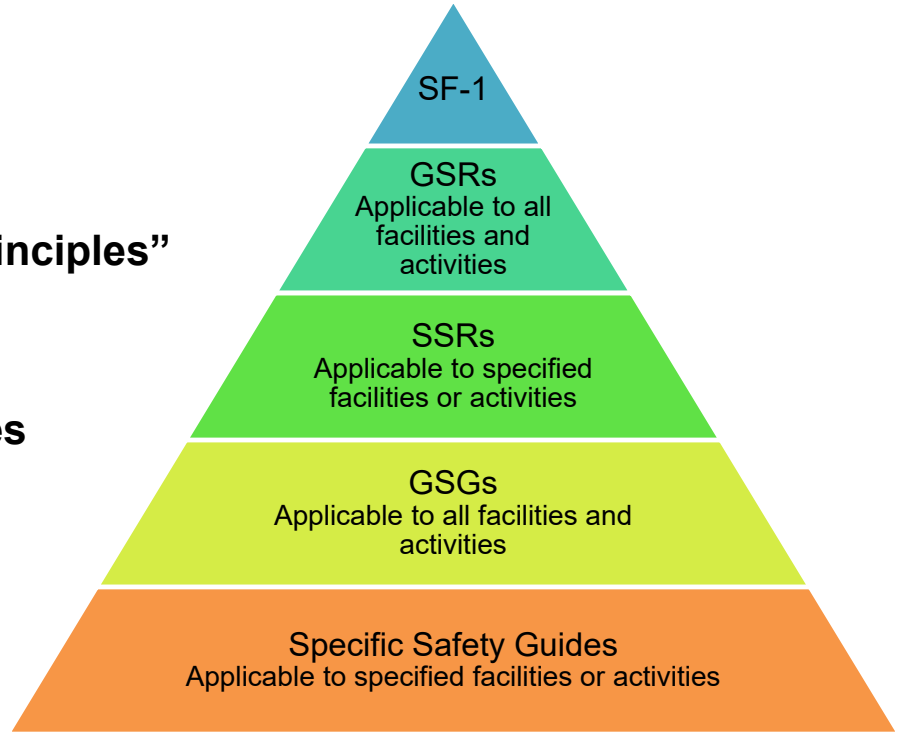
- Establish the **fundamental safety objective** and **ten safety principles** as well as their intent and purpose
- Due to the generic nature, it is **fully applicable** to **fusion facilities**

General Safety Requirements

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

Specific Safety Requirements

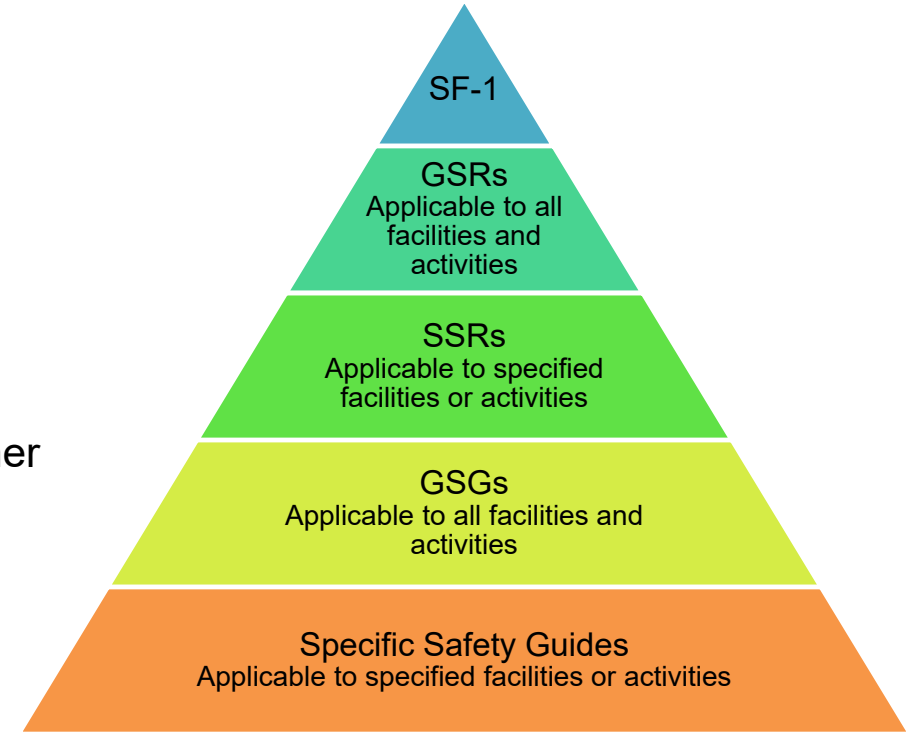
- Could be applied in principle



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.)

Acknowledgement

The authors are grateful to the European Commission for funding the documented activities. The results have been prepared for the European Commission however it reflects the views only of the authors, and the Commission cannot be held responsible for any use which may be made of the information contained therein.

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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