IAEA TECDOC-1874 の概要

「IAEA, Hierarchical Structure of Safety Goals for Nuclear Installations, IAEA-TECDOC-1874, 2019」の本文および付録の記載から、重要な点（下線）を抽出し、個人の意見（【…】）を記載。

本文

1. 概要

1.1. 背景

- 【人と環境を守るため、安全目標として詳細な技術的な要件と基準を定めることが必要である】It is an important and at the same time challenging task to determine a set of safety requirements and criteria that would aid in answering the question, How safe is safe enough? In order to achieve the fundamental safety objective of protecting people and the environment from harmful effects of ionizing radiation, a set of detailed technical requirements and criteria, both qualitative and quantitative, can be formulated as safety goals.
- 【安全性とリスクを判断する指標値が必須】Criteria
  - ✧ IAEA/SF-1[1] Principle 6: Limitation of risks to individuals. Measures for controlling radiation risks must ensure that no individual bears an unacceptable risk of harm. Criteria for what constitutes an 'unacceptable risk' need to be established.
  - ✧ IAEA General Safety Requirements (No. GSR Part 4)[2] Requirement 16: Criteria for judging safety. Criteria for judging safety shall be defined for the safety analysis.
  - ✧ 【一部の国は INSAG-12[3]を参考したが、定性的と定量的目標を統合した一貫性がある安全目標の階層構造を確立必要がある】Several countries refer to the INSAG-12 report, as a basis for their national set of quantitative safety goals. The growing importance of establishing a consistent and coherent hierarchy of safety goals for NPPs and other nuclear installations on the basis of the consideration of both quantitative and qualitative

[1] IAEA/SF-1 (2006), Fundamental safety principles, Page 11.
[2] IAEA/GSR Part 4 (2016), Safety assessment for facilities and activities, Rev.1, Page 25.
[3] IAEA/INSAG-12 (1999), Basic safety principles for nuclear power plants 75-INSAG-3 Rev. 1. General objective: To protect individuals, society and the environment by establishing and maintaining in nuclear power plants an effective defense against radiological hazard. Radiation protection objective: To ensure in normal operation that radiation exposure within the plant and due to any release of radioactive material from the plant is as low as reasonably achievable, economic and social factors being taken into account, and below prescribed limits, and to ensure mitigation of the extent of radiation exposure due to accidents. Technical safety objective: prevent with high confidence accidents in nuclear plants; to ensure that, for all accidents taken into account in the design of the plant, even those of very low probability, radiological consequences, if any, would be minor; and to ensure that the likelihood of severe accidents with serious radiological consequences is extremely small. The target for existing nuclear power plants consistent with the technical safety objective is a frequency of occurrence of severe core damage that is below about 10^{-4} events per plant operating year.

concepts has been widely recognized.

- 【論点抽出】
  - ✧ 安全とリスクを判断する指標値として、安全目標の適切性
  - ✧ 日本の安全目標の階層構造の設計（例 1:本 TECDOC の Page 16,17, 例 2:Table 1）

Table 1 安全目標の階層構造の設計例[4]

<table>
<tr><td>最上位目標
（原子力安全の目的）</td><td colspan="5">原子力の施設と活動に起因する放射線の有害な影響から人と環境を防護する</td></tr>
<tr><td>上位目標</td><td colspan="3">放射線の放射や放射性物質の拡散による公衆の健康リスクは，公衆の日常生活において現存する健康リスクの合計を有意に増加させない水準に抑制されるべきである</td><td colspan="2">放射線の放射や放射性物質の拡散により環境を害し，或いは広範囲にわたる社会的混乱をもたらすリスクは，他の原因による事故や自然事象がもたらす同様のリスクの合計を有意に増加させない水準に抑制されるべきである</td></tr>
<tr><td>中位目標</td><td rowspan="2">通常運転時安全基準</td><td rowspan="2">設計基準事象に対する安全基準</td><td>重大事故時の健康リスクに対する確率論的定量目標</td><td rowspan="2">重大事故に対する安全基準
（Cs^{137}放出量
100 TBq 未満）</td><td>重大事故時の社会的リスクに対する確率論的定量目標</td></tr>
<tr><td>下位目標
（Surrogate）</td><td>性能目標
（CDF/CFF 目標）</td><td>性能目標
（CDF/CFF 目標，Cs^{137}放出量
100 TBq 超頻度＜ 10^{-6}/炉年）</td></tr>
</table>

  - ✧ 安全目標における一貫性の定義（層と層の一貫性、異なる施設間の一貫性、安全目標と深層防護の一貫性、など）

1.2. 【目的：安全目標の確立（階層化）、活用（コンプライアンス評価、規制と許認可申請、IRIDM と安全コミュニケーション）】Objectives

- The primary objective of this TECDOC is to assist in creating a greater understanding of the establishment, use and communication of safety goals for nuclear installations in Member States.
- This TECDOC sets out the advantages and benefits of developing a hierarchical organization of safety goals. It provides practical guidance and examples on establishing a consistent and coherent hierarchical set of safety goals for nuclear installations.
- The TECDOC provides practical guidance on the safety goals that are needed for use in an integrated risk-informed decision making (IRIDM) process. The use of safety goals for communicating with stakeholders and other purposes is also discussed.
- 【用語について、当初は枠組み（Framework、フレームワーク）を利用したが、現在階層構造（Hierarchy、ヒエラルキー）に統一した】
- 【本 TECDOC は階層構造の利点のみを紹介するが、具体的な安全目標の策定の責任者が各国の機関である】This TECDOC discusses the advantages of a hierarchical structure of safety goals and their use but does not recommend any particular set of safety goals because it is the responsibility of each Member State to determine how nuclear safety is assured.
- 【論点抽出】
  - ✧ 安全目標の活用先

[4] 山口彰（2023），外的事象に対する原子力安全の基本的考え方の実効的な取り組み(2) 安全目標の役割と普及，原子力学会 2023 年春の年会，2C_PL02

✧ 安全目標を策定する責任者

1.3. Scope

- The scope of this TECDOC is concerned only with radiation and nuclear safety.
- 【1986 年 USNRC 安全目標政策声明について、原子力発電所の運転が対象で、燃料サイクルのリスクなどが対象外[5]】
- 【論点抽出】
  ✧ スコープの設定について

2. 【安全目標の階層化】A General Hierarchy of Safety Goals

2.1. Approaches

- 【WENRA、MDEP と NPSAG の階層構造を参考し、安全目標の階層には、社会のレベルから施設のレベル、技術に依らないレベルから技術に固有のレベル、基本的安全目標のレベルから個別安全対応のレベルと複数種類の階層を関連づけたことである】The hierarchical approach covers the entire range of levels, from the highest (society) to the lowest (technology and facility specific) level, referring three examples of safety goals hierarchies developed by WENRA (Western European Nuclear Regulators Association), MDEP (Multinational Design Evaluation Project) and NPSAG (The Nordic PSA Group).

2.2. Types of safety goals

- 【定性的、定量的、決定論的、確率論的安全目標が階層構造に存在する。上位目標が施設の運転期間や具体的な施設と関連しなく、下位目標が運転期間に依存する場合もある】The highest level safety goal would be expected to remain unchanged over all life cycle phases, while lower level safety goals may be different for different life cycle phases, and may also change during the life time of an installation. Both operational states and accident conditions need to be considered.

[5] USNRC (1986), Safety goals for the operations of nuclear power plants, policy statement, 51 Federal Register 30028. This policy statement focuses on the risk to the public from nuclear power plant operation. These are the risks from release of radioactive materials from the reactor to the environment from normal operations as well as from accidents. The Commission will refer to these risks as the risks of nuclear power plant operation. The risks from the nuclear fuel cycle are not included in the safety goals. These fuel cycle risks have been considered in their own right and determined to be quite small. The possible effects of sabotage or diversion of nuclear material are also not presently included in the safety goals. At present there is no basis on which to provide a measure of risk on these matters.

Figure 1 Types of safety goals and field of application

2.3. Hierarchical approach to safety goals

- 【階層構造の汎用性】The hierarchy is to be applicable to all types of nuclear installations. The hierarchy is to be applicable to all relevant lifetime stages. The hierarchy is to cover the applicable states of the installation, e.g. operational states and accident conditions.
- 【IAEA 基本安全原則及び安全標準との整合性】The hierarchy is to complement and be in agreement with the structure of the IAEA Fundamental Safety Principles and Safety Standards.
- 【深層防護との一貫性】The hierarchy is to be consistent with the structure and intents of defense-in-depth and support its implementation.
- 【下位の層を詳細化】The Top Level safety goals express overall requirements on society level, while lower levels will successively detail the top level goals.
- 【各層の安全目標の一貫性】Safety goals on different levels are to be consistent and traceable, allowing to derive lower level goals from higher level ones.
- 【上位の安全目標が Technology-neutral、下位の安全目標が Technology-specific】Higher level safety goals are as far as possible to be technology neutral, while lower level goals are expected to be increasingly technology specific.
- 【定性と定量的安全目標が同時に存在する】The hierarchy is to include qualitative as well as quantitative safety goals.
- 【分かりやすさ、使いやすいさ、コミュニケーションの容易度を考慮】The structure is to be clearly and unambiguously defined, making it easy to understand, implement and communicate.

2.3.1. 【IAEA の階安全目標階層構造概念】Proposed hierarchy of safety goals

- IAEA の提案にもあるように、安全目標は、最上階層に広く社会に理解・受容される一般的な高位目標を据えたうえで、多面的な観点でそれらを下階層の具体的な活動に係る目標に展開していく必要がある。即ち最上階層の目標は、個々の技術に依らず、工学システム全体を見据えて社会全体として目指すべく設定される。そして、最上階層目標から下層目標へ展開するプロセスは多様であるが、それぞれが最終的には具体的かつ実行可能な行動に落とし込まれ、目標を具現化するものとならねばならない[6]。

[6] 弥生研究会 安全目標に関する研究会,「安全目標」再考 - なぜ安全目標を必要とするのか?–, 7 ページ, UTNL-R-497, 2018 年 3 月

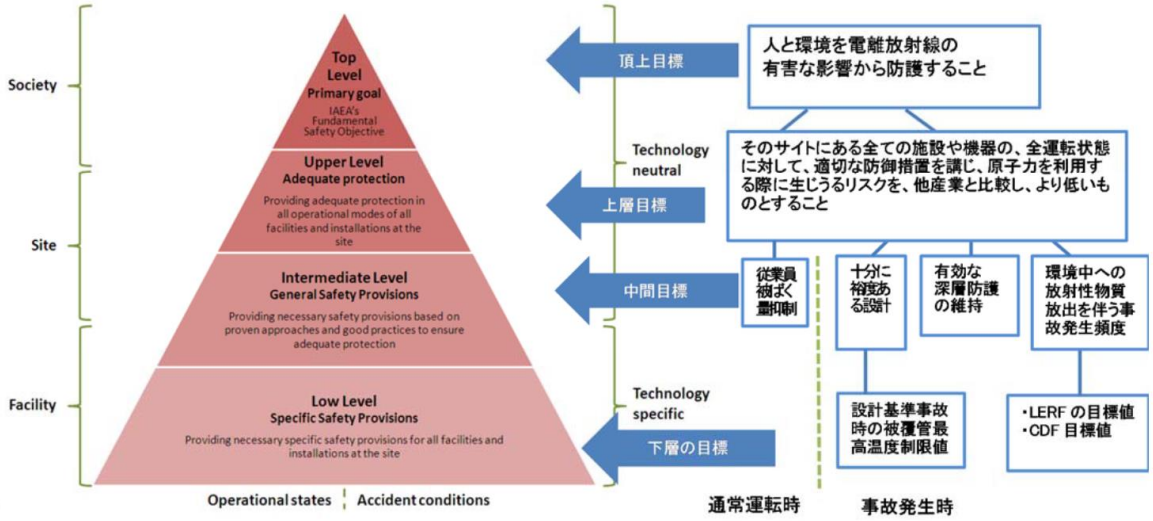

Figure 2 Proposed hierarchy of safety goals[7]

2.3.2. 【最上位の安全目標は、原子力基本法で定義されることが普通だが、規制当局により策定されることもある（例えば、原子力規制委員会の使命[8], USNRC の Mission[9]）】Top level safety goals

- In many countries, nuclear safety is ultimately governed by qualitative safety goals at the society level, which are often defined in nuclear legislation but may also be issued by regulatory authorities. These safety goals may have a wider scope than nuclear.

2.3.3. Upper level safety goals

- Upper Level safety goals are expressed in more detail than the Top Level safety goals, providing a bridge to the more detailed technical safety goals at the Intermediate and Low Levels. Upper Level safety goals are typically technology neutral and have a site-wide scope thus providing a basis for Intermediate and Low Level safety goals

2.3.4. Intermediate level safety goals

- Intermediate Level safety goals are normally to a large extent technology neutral but can include the highest level safety goals for application to specific technologies. Intermediate Level safety goals are aimed to cover crucial general safety principles and provisions such as defense-in-depth, safety margins, physical barriers (including considerations related to independence and protection of barriers), and redundancy and independence.

2.3.5. Low level safety goals

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[7] 弥生研究会 安全目標に関する研究会,「安全目標」再考 - なぜ安全目標を必要とするのか?–, 11 ページ, UTNL-R-497, 2018 年 3 月

[8] 原子力規制委員会, 使命：原子力に対する確かな規制を通じて、人と環境を守ることが原子力規制委員会の使命である, https://www.nra.go.jp/nra/gaiyou/idea.html

[9] USNRC, Mission: The NRC licenses and regulates the Nation's civilian use of radioactive materials to provide reasonable assurance of adequate protection of public health and safety and to promote the common defense and security and to protect the environment. https://www.nrc.gov/about-nrc.html

- The Low Level safety goals are technical and aim at assuring the nuclear installation meets the higher level safety goals, by addressing siting, design and operational aspects of a nuclear installation. Quantitative deterministic safety goals may relate to maximum or minimum values of crucial parameters, such as fuel temperature, pressure or water levels. Quantitative probabilistic safety goals are expressed as frequencies or probabilities of unacceptable states or consequences. Low level safety goals can constitute requirements or acceptance criteria for design and operation.
- 【論点抽出】
  - ✧ 中間レベルの安全目標と深層防護、安全裕度の関係
  - ✧ 下位の決定論的と確率論的安全目標

3. 【安全目標の導出と定義】Derivation of Safety Goals

3.1. 【Top-Down 的な方法】Derivation

- These higher-level safety goals could be qualitative and/or quantitative, and aim at helping in making the assessment that nuclear installations have achieved an acceptable level of safety for individuals and society in general. The determination of Intermediate and Low Level safety goals makes possible the coherent use of a set of safety goals at the organizational and technical level that relates to the established safety goals on higher levels.
- Although safety goals on Top and Upper Levels are less likely to be changed (particularly if legally established), safety goals on the lower levels may be changed more frequently.

3.2. 【安全目標の定義にステークホルダーの役割】The roles of stakeholders involved in the definition of safety goals

- 【安全目標は「全ての国民のためのもの」ということであり、「全ての国民が安全目標のステークホルダー」】Safety goals are intended to reflect the interests of the public, not only those who are directly involved in nuclear safety.
- 【最上位の安全目標の策定責任者は国の政府と機関、その下の層の策定に規制当局の役割が重大で、下層の安全目標の策定に原子力事業者の役割も重要】At the higher levels (mostly Top and Upper levels), it is the responsibility of Government, or one of its agencies, to define what constitutes an acceptable level of risk. These safety goals will be enshrined in legal or other mandatory documents.
- At levels below the Top Level, as the goals become more technology and facility specific (mostly Intermediate and Low Levels), the role of the regulatory body becomes more important.
- The input of various expert technical organizations and the licensee becomes more significant in the definition of the two lower level safety goals. The input of various expert technical organizations and the licensee becomes more significant in the definition of the two lower level safety goals. In some countries, Low Level safety goals may be defined by the licensees and approved or accepted by the regulatory body.
- This progression is outlined in the IAEA Safety Fundamentals which states “The government is

responsible for the adoption within its national legal system of such legislation, regulations, and other standards and measures as may be necessary ...” and “Governments and regulatory bodies thus have an important responsibility in establishing standards ...” The Safety Fundamentals also states that the licensee must fulfil its “responsibilities … in accordance with applicable safety objectives and requirements as established or approved by the regulatory body”. Further statements include, “In addition, detailed criteria may be developed to assist in assessing compliance with these higher level objectives, principles and requirements, including risk criteria that relate to the likelihood of anticipated operational occurrences or the likelihood of accidents occurring that give rise to significant radiation risks.”

- 【論点抽出】
  - ✧ 安全目標のステークホルダーを明確に
  - ✧ 各層の安全目標の策定にその責任者と関係者を明確に

3.3. 【定義と各層間の相関関係】Safety goals within the hierarchy

3.3.1. Top level safety goals

3.3.2. Upper level safety goals

- 【頂上目標：一般的に、人と環境を守る】The definition of Upper Level safety goals determines the requirements for adequate protection. This interpretation is an important and key step for the feasibility and acceptability of the hierarchical structure of safety goals.
- 【上層目標：最上位の目標を一層具体化するため、リスクとの概念（明確や曖昧的に）を導入し、Adequate Protection の要件を決定する。この層は、安全目標の可用性と受容性を強く影響する。例えば、キーワードとして、放射線被ばく、Public perception としての土地汚染と癌発生リスク、緊急時避難計画、施設運用のリスク便益分析】The Upper Level safety goals imply that justification of the facility or activity in terms of providing an overall benefit is required before a facility can operate or an activity is performed. This justification is generally made at a government or regulatory body level depending on the nature of the facility or activity. Justification requires assessment of the benefit and whether it can be achieved by the facility or activity in a way that does not outweigh the radiation risks.

3.3.3. 【中間目標：防護の最適化、リスクの限界】Intermediate safety goals

- Intermediate Level safety goals cover crucial technical safety provisions relating to optimization of protection and limitation of risks such that general safety principles are addressed e.g. defense-in-depth, safety margins, physical barriers (including considerations related to independence and protection of barriers), and redundancy and independence. Safety goals on Intermediate Level also include site level requirements, e.g. related to risk of total releases from the site rather than from individual facilities on the site (e.g. overall LRF or LERF for the site), or site level requirements related to the capability to handle external hazards (e.g. design of site protective features, effects on shared resources or systems or on emergency preparedness in cases where several facilities are subject to the same event).
- 【放射線被ばくの防護が十分】Radiation Protection Safety Goals for Normal Operations

Intermediate Level safety goals for limitation of risks are usually expressed as dose limits (which are based on the recommendations of the ICRP) that are not to be exceeded but with the requirement to reduce doses below these levels as low as reasonably achievable (ALARA) taking account of societal and economic factors.

- 【深層防護が十分】Effective Defense-in-Depth
- 【冗長性と多様性が十分】Sufficient Redundancy and Diversity
- 【バリアの機能の防護と独立性、安全機能】Independence, Protection of Barriers, and Safety Functions
- 【バリアの有効性】Effective Barriers: the fuel matrix, the fuel cladding, the boundary of the reactor coolant system and the containment structure.

3.3.4. Low level safety goals

- For operational states, Low Level safety goals are in general related to the performance of SSCs and the provision of the operational requirements, e.g. operating procedures for normal operation and for anticipated operational occurrences. Whilst safety goals related to external hazards at the site level are included in the Intermediate Level safety goals, detailed requirements in the form of Low Level safety goals may be included within the design basis (e.g. seismic fragility-related requirements for SSCs). The Low Level safety goals may include detailed specification of the safety margins. These margins may be dependent on the technical specifications of SSCs, properties of materials used and production processes, etc. Thus, Low level safety goals are often defined on one or more of the following headings for an installation or facility:
- As part of the Low Level safety goals, there may be multiple sub-levels of safety goals, defining subsidiary (or surrogate) goals. These also need to be consistently defined, e.g. regarding safety goals addressing LRF and CDF.
- Deterministic safety goals may include:
  - ✧ Required number of trains in safety systems
  - ✧ Maximum fuel clad temperature
  - ✧ Design requirements against internal hazards and external hazards
- Probabilistic safety goals, i.e. quantitative safety goals specifying the frequency of a specific consequence, may include:
  - ✧ Off-site consequence level (could correspond to PSA Level 3)
  - ✧ Radioactive release from plant level (could correspond to PSA Level 2)
  - ✧ Core or fuel damage level (could correspond to PSA Level 1)
  - ✧ Lower technical criteria; numerous possibilities exist (barrier strength, safety function, safety system, etc.)
- 【論点抽出】
  - ✧ 階層構造を用いた安全目標の導出は Top-Down 方法
  - ✧ 頂上目標は国の法律で定められることで、上層目標の設計がその法律の施行に重

要であり、リスクの概念を適切に利用する必要がある

- ✧ 頂上目標と中間目標の策定に、規制当局の責任が重大で、規制の一貫性
- ✧ 決定論的目標と確率論的目標を含めた下層目標の多様性
- ✧ 下層目標の策定方法

4. 【安全目標の活用方法】Applications of a Hierarchy of Safety Goals

4.1. 【リスク管理者によるコンプライアンス評価：リスク管理者が果たすべきリスク管理抑制水準の設定のために活用。上位の安全目標の達成度を確認するのが困難だが、下位の目標に対して技術的な検証を実施できるので、コンプライアンス評価が可能。】Compliance assessment: Assessing whether the overall objectives of safety goals are met through assessment of safety cases and on-site inspection.

- The general approach for assessing compliance with the hierarchical structure of safety goals is a bottom-up process.
- Compliance with top level and upper level safety goals: It is not expected that licensees are required to demonstrate compliance directly at these levels. Due to their very general statements, qualitative safety goals are not directly enforceable. Therefore, they have to be translated into numerical objectives that can be compared with experience and with analytical predictions.
- Compliance with intermediate level safety goals: This set of safety goals allows explicit assessment of compliance of a site's safety performance. Generally, demonstration of compliance at this level is provided by the licensee when seeking approval or renewing an operating license from the regulatory body.
- 【規制当局が、標準、検査、解析手法等を用いて下位安全目標のコンプライアンス評価を実施する】Compliance with low level safety goals: Technology specific safety goals are related to safety objectives of SSCs, and are partially defined in national and international industrial standards, or national and international nuclear safety standards.
  - ✧ Compliance with many Low Level safety goals requires the use of analytical techniques (e.g. thermal hydraulic analysis or PSA). These analyses are to be carried out by the licensee and used in the safety management of the facility or activity. The compliance assessment is reviewed by the regulatory body.
- 【定量的安全目標に対するコンプライアンス評価は、決定論的や確率論的な手法を用いて評価する。平均値と基準値を比較して合否を判定する場合、不確かさを考えないといけない】Compliance with quantitative safety goals: Quantitative safety goals are defined mainly on the lower levels of the hierarchical structure of safety goals. Examples of quantitative values that can be subject to safety goals are probability/frequency figures for various types of risks or conditions that may result in risk (core damage frequency, barrier strength, release frequencies etc.) and requirements related to different plant states.
- 【規制当局が、事業者の安全評価報告書等をレビューすることにより、定性的な安全目標のコンプライアンス評価を行う】Compliance with qualitative safety goals: Demonstrating

compliance with qualitative safety goals is not as straightforward as for quantitative safety goals. Concepts such as, effective DiD features, operating procedures including Severe Accident Management Guidelines (SAMG), radioactive waste management policies, and overall requirements for management of safety are important factors. These concepts describe generally accepted practices that, when followed, permit nuclear sites to meet the qualitative safety goals. Assessment of compliance with these goals may be achieved by a review of the licensee's safety analysis, including organizational safety policies that have been established.

- Trade-off and integrated compliance

4.2. 【規制と許認可申請への活用例：設計、運転、改定、メンテナンス、サイトレベルの要件確認、緊急時防災計画、定期安全レビュー】Regulatory and licensing applications

4.2.1. Application of safety goals in design

- The hierarchy of safety goals, as an intrinsic part of the design approach, also allows engineering, management and quality assurance processes to be used in demonstrating compliance with safety goal requirements.

4.2.2. Application of safety goals during operations

- Operating limits and conditions
  - ✧ The hierarchical structure of safety goals can assist in determining how to handle these situations, e.g. supporting the development of allowed outage times addressing the requirement to control risk increase due to equipment unavailability.
- Control of modifications
  - ✧ When undertaking modifications to the facility or operational procedures during its lifecycle, safety goals can be used for ensuring that safety is maintained.
- Maintenance planning
  - ✧ Safety goals can be used to assist in planning maintenance activities to ensure that safety is maintained when SSCs important to safety are taken out of service.
- Site wide considerations for multi-facility sites
  - ✧ In a hierarchy of safety goals, the identification of safety requirements for a site and the individual facilities on the site allows better understanding of the relative risk posed by each of these facilities.
- Emergency preparedness
  - ✧ The structure of safety goals can provide the basis for developing this program by setting both high level societal goals and detailed technology requirements.
- Periodic safety review
  - ✧ When a periodic safety review (PSR) is performed, the safety goals can be used as a baseline, against which to review the current safety provisions and past operating performance.

4.3. 【IRIDM への活用】Use of safety goals in integrated risk informed decision making (IRIDM)

- The main goal of the IRIDM process is to define the most balanced decision among several

possible options by considering different key elements (e.g. mandatory requirements, deterministic, probabilistic, economical, security considerations). One of the major factors that has to be taken into consideration in the IRIDM process (typically falling in the mandatory requirements considerations) is the level of compliance with existing safety goals. The weighted approach employed in the IRIDM process allows assignment of different importance to the specific levels of safety goals being considered in the decision making.

4.4. 【適切なリスク管理の実施には、これらリスク管理者の組織内で、リスク管理者間で、またリスク管理者と公衆の間において、リスク情報とリスク認識とを共有することが不可欠であり、安全目標はそのコミュニケーションにおける共通言語として活用されることが期待される】Safety communication

- Communication between the regulatory body and the public
  - ✧ IAEA recommends that all countries should create and implement instruments that enhance transparency, openness and participation of the interested parties considering the guidance provided by IAEA Safety Standards Series No.GSG-6. In this context, the use of safety goals could be an invaluable aid to developing understanding the way in which the risks from ionizing radiation are being managed.
- 【規範的な規制制度や Performance-based 規制制度においても、安全目標は有効的である】Communication between the regulatory body and the licensee/license applicant
  - ✧ The licensee needs to understand the regulatory requirements to be complied with and how they assure that the higher level safety goals are achieved.
  - ✧ In a prescriptive regime, the regulatory body may also set the lower level goals for the license application. The structure of safety goals may help demonstrate to the licensee that the goals are both necessary and sufficient to assure safety.
  - ✧ In a goal-setting regime, the licensee may be responsible for defining the lower level requirements. Therefore, the structure of safety goals provides an important tool to demonstrate that the lower level goals will satisfy the higher level goals.
- Communication between the operating organization and the public
  - ✧ An adequate level of safety in terms that are understandable and meaningful to the public (the Top and Upper Level goals can assist this);
  - ✧ A structure for implementation at the technical level which gives confidence that all elements of safety provision are adequately covered.
- 【課題抽出】
  - ✧ 安全目標を活用するための課題と留意事項[10]
    - – 活用の方針を明確に示すこと
    - – 指針・標準類を整備すること

[10] 弥生研究会 安全目標に関する研究会,「安全目標」再考 - なぜ安全目標を必要とするのか? –, 20 ページ, UTNL-R-497, 2018 年 3 月

- 活用の実績を積み重ねること
- 評価の不確かさを踏まえること
- 評価技術を深化・拡張すること

✧ コンプライアンス評価に、責任の明確に示すことを含め、上記の方針・指針・標準を系統的に整備する

5. The structure starts from the overarching requirements for safety, that are detailed further in a hierarchical top-down way. A description of the structure and the general features of safety goals at various levels within the suggested four-level hierarchy have been provided.
   - For countries which are in the beginning of development of their nuclear power programs, the approach described in this TECDOC may assist in developing a consistent and coherent view of the safety goals to be pursued.
   - For countries with developed nuclear power programs, this TECDOC may be useful in benchmarking the existing safety goals for consistency and coherence in covering all aspects important to nuclear safety.
   - 【論点の分類】
     ✧ 安全目標の定義
     ✧ 安全目標の確立（階層化）
     ✧ 安全目標の活用

付録

6. 【各国の安全目標の紹介を省略】Safety Goals in Different Countries
   - Canada
   - Germany
   - Sweden
   - UK
   - US

7. 【参考した階層構造の例を省略】Examples of Safety Goals Hierarchies
   - WENRA
   - MDEP
   - NPSAG

8. Example of an Approach for Defining Low Level Probabilistic Safety Goals (Objectives)

8.1. Main constituents of a probabilistic safety goal【4 つの要素】
   - Definition
   - Scope
   - Target

- The application of the safety goal

8.2. 【下位の安全目標の構成に 4 つの要素が必要、影響の定義、影響の指標、リスク指標、リスク指標の許容値】Definition of a probabilistic safety goal: a consequence, a metric for the consequence, a risk metric, and acceptance level of the risk metric

8.3. Off-site consequence level (could correspond to PSA Level 3)

Concept	Definition	Example
Consequence	Defines the health effects and the individual/group to which the safety goal applies.	Accident resulting in a dose to individuals off-site.
Metric	Qualifies the consequence (in this case "health effect") in terms of a measurable magnitude.	Dose received in the interval 10 to 100 mSv
Risk metric	Defines how the risk is to be expressed.	Frequency of achieving a dose rate in the interval defined.
Frequency/ probability	Defines specific levels related to the frequency/probability.	The UK approach involves the definition of a basic safety limit (BSL) not to be exceeded (except in exceptional circumstances), and a basic safety objective (BSO), below which the risk is considered to be broadly acceptable. BSL: 1 x E-4 / year BSO: 1 x E-6 / year

8.4. Radioactive release from plant level (could correspond to PSA Level 2)

Concept	Definition	Example
Consequence	Defines the consequence related to the release.	Unacceptable release with respect to long-term ground contamination.
Consequence measure	Qualifies the consequence (in this case "release causing long-term ground contamination") in terms of a measurable magnitude.	**Sweden:** Release of Cs-137 in excess of an amount corresponding to 0.1% of the core inventory in a 1800 MWt reactor (equivalent to about 103 TBq of Cs-137). **Finland:** Release of > 100 TBq of Cs-137.
Risk metric	Defines how the risk of exceeding the specified consequences is to be expressed.	**Sweden:** No risk metric has been defined by SSM. However, it is stated that a release exceeding the limit shall be "extremely unlikely", indicating consideration of an occurrence frequency. **Finland:** Frequency of exceeding the release limit.
Frequency/ probability	Defines specific levels related to the frequency/probability.	**Sweden:** "Extremely unlikely" has been interpreted to indicate a limit between 10^{-6} and 10^{-7} per year. **Finland**: The criterion is defined as a frequency limit, which is set to $5 \cdot 10^{-7}$ per year.

8.5. Core or fuel damage level (could correspond to PSA level 1)

Concept	Definition	Example
Consequence	Defines the consequence related to the fuel overheating.	Severe core damage
Metric	Qualifies the consequence (in this case "severe core damage") in terms of a measurable magnitude.	"Severe" is not qualified, but previous versions of the safety policy have referred to 10 CFR 50.46 (local fuel temperature above 1204 ºC).
Risk metric	Defines how the risk is to be expressed.	Frequency of exceeding the limit. *Note: As long as "severe" is not defined, there is some vagueness in the definition of the risk metric.*
Frequency/ probability	Defines specific levels related to the frequency/probability.	The criterion is defined as a frequency target, which is set to $1 \cdot 10^{-5}$ per reactor year.

8.6. Lower technical criteria (SSC Level); numerous possibilities exist in terms of PSA and/or non-PSA criteria (barrier strength, reliability of safety function, reliability of safety system, etc.)

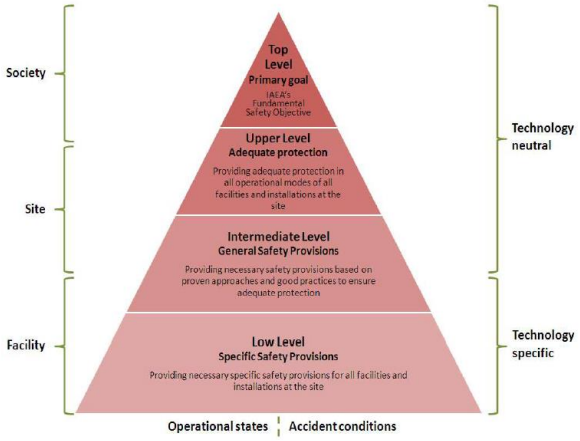
Concept	Definition	Example
Consequence	Defines the consequence related to the fuel overheating.	Loss of containment integrity (resulting in an unacceptable release) after core damage has occurred.
Metric	Qualifies the consequence (in this case "loss of containment integrity") in terms of a measurable magnitude.	Must be based on the metric already defined for the criteria on the levels of core damage and release.
Risk metric	Defines how the risk is to be expressed.	Probability of exceeding the metric related to the release criterion, after the metric related to the core damage criterion has been exceeded.
Frequency/ probability	Defines specific levels related to the frequency/probability.	The criterion is defined as a conditional probability, with a limit set to 0.1. *Note: This criterion can be used both if the higher level criteria are defined as single criteria and if they are ALARP criteria with a limit and an objective.*

9. まとめ

- IAEA-TECDOC-1874 から抽出した論点を下記の分類で整理する

論点の分類	論点
1. 必要性と目的	• 安全とリスクを判断する指標値として、安全目標の適切性 – 人と環境を守るため、安全目標として詳細な技術的な要件と基準を定めることが必要である • 安全目標を策定する責任者 – 最上位の安全目標の策定責任者は国の政府と機関、その下の層の策定に規制当局の役割が重大で、下層の安全目標の策定に原子力事業者の役割も重要 • 安全目標のステークホルダーを明確に – 安全目標は「全ての国民のためのもの」ということであり、「全ての国民が安全目標のステークホルダー」
2. 位置づけ・活用方法とその効用	• 安全目標を活用するための課題と留意事項 – 活用の方針を明確に示すこと – 指針・標準類を整備すること – 活用の実績を積み重ねること – 評価の不確かさを踏まえること – 評価技術を深化・拡張すること • コンプライアンス評価に、責任の明確に示すことを含め、上記の方針・指針・標準を系統的に整備する – 定量的安全目標に対するコンプライアンス評価は、決定論的や確率論的な手法を用いて評価する。平均値と基準値を比較して合否を判定する場合、不確かさを考えないといけない – 規制と許認可申請への活用例：設計、運転、改定、メンテナンス、サイトレベルの要件確認、緊急時防災計画、定期安全レビュー • IRIDM への活用 • 適切なリスク管理の実施には、これらリスク管理者の組織内で、リスク管理者間で、またリスク管理者と公衆の間において、リスク情報とリスク認識とを共有することが不可欠であり、安全目標はそのコミュニケーションにおける共通言語として活用されることが期待される

3. 全体検討プロセス	• 安全目標の階層構造の設計（例 1:本 TECDOC の Page 16,17, 例 2:下記の図と表） 安全目標の階層構造の設計例



<table>
<tr><td>最上位目標
（原子力安全の目的）</td><td colspan="5">原子力の施設と活動に起因する放射線の有害な影響から人と環境を防護する</td></tr>
<tr><td>上位目標</td><td colspan="3">放射線の放射や放射性物質の拡散による公衆の健康リスクは，公衆の日常生活において現存する健康リスクの合計を有意に増加させない水準に抑制されるべきである</td><td colspan="2">放射線の放射や放射性物質の拡散により環境を害し，或いは広範囲にわたる社会的混乱をもたらすリスクは，他の原因による事故や自然事象がもたらす同様のリスクの合計を有意に増加させない水準に抑制されるべきである</td></tr>
<tr><td>中位目標</td><td rowspan="2">通常運転時安全基準</td><td rowspan="2">設計基準事象に対する安全基準</td><td>重大事故時の健康リスクに対する確率論的定量目標</td><td rowspan="2">重大事故に対する安全基準
（Cs^{137}放出量
100 TBq 未満）</td><td>重大事故時の社会的リスクに対する確率論的定量目標</td></tr>
<tr><td>下位目標
（Surrogate）</td><td>性能目標
（CDF/CFF 目標）</td><td>性能目標
（CDF/CFF 目標，Cs^{137}放出量
100 TBq 超頻度＜ 10^{-6}/炉年）</td></tr>
</table>

- 安全目標における一貫性の定義（層と層の一貫性、異なる施設間の一貫性、安全目標と深層防護の一貫性、など）
  - 一部の国は INSAG-12 を参考したが、定性的と定量的目標を統合した一貫性がある安全目標の階層構造を確立必要がある
  - WENRA、MDEP と NPSAG の階層構造を参考し、安全目標の階層には、社会のレベルから施設のレベル、技術に依らないレベルから技術に固有のレベル、基本的安全目標のレベルから個別安全対応のレベルと複数種類の階層を関連づけたことである
  - 中間レベルの安全目標と深層防護、安全裕度の関係
- 階層構造を用いた安全目標の導出は Top-Down 方法
- 頂上目標は国の法律で定められることで、上層目標の設計がその法律の施行に重要であり、リスクの概念を適切に利用する必要がある
- 決定論的目標と確率論的目標を含めた下層目標の多様性とその策定方法

4. 対象範囲	• スコープの設定について – 1986 年 USNRC 安全目標政策声明について、原子力発電所の運転が対象で、燃料サイクルのリスクなどが対象外 • 規範的な（Prescriptive）規制制度（独、仏）や Goal-setting (Risk-informed, Performance-based)規制制度（英、米、加）においても、安全目標は有効的である
5. 目標・指標の種類と論理構造	• 頂上目標：一般的に、人と環境を守る • 上層目標：最上位の目標を一層具体化するため、リスクとの概念（明確や曖昧的に）を導入し、Adequate Protection の要件を決定する。この層は、安全目標の可用性と受容性を強く影響する。例えば、キーワードとして、放射線被ばく、Public perception としての土地汚染と癌発生リスク、緊急時避難計画、施設運用のリスク便益分析 • 中間目標：防護の最適化、リスクの限界 • 下位の安全目標の構成に 4 つの要素が必要、影響の定義、影響の指標、リスク指標、リスク指標の許容値
6. 指標の判断基準と妥当性確認方法	• 安全目標の階層構造は、国の特性を反映した（Country-specific）リスク指標（下位の決定論的と確率論的安全目標）を利用することに親和性がある。 • 各国の安全目標の階層構造の比較 – USNRC の安全目標と UK HSE のキャロットモデルとの比較
7. 社会受容・合意形成及び実装に向けた課題	• 日本の規制制度を反映し、分かりやすい安全目標の階層構造を設計する必要がある – 階層構造の汎用性 – IAEA 基本安全原則及び安全標準との整合性 – 深層防護との一貫性 – 下位の層を詳細化 – 各層の安全目標の一貫性 – 上位の安全目標が Technology-neutral、下位の安全目標が Technology-specific – 定性と定量的安全目標が同時に存在する – 分かりやすさ、使いやすいさ、コミュニケーションの容易度を考慮

以上