Fundamental principles of protection and safety for nuclear power

A proposed basis for a harmonized approach to radiation protection and nuclear safety

by
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The purpose of this report is to present a draft of a coherent set of fundamental principles of protection and safety for nuclear power, which might be considered as a basis for developing formal principles for an eventual *de jure* adoption by governments. The objective is to facilitate agreements for a global harmonization on criteria to offset perceived threats from nuclear power to health and the environment.

Prologue

Over this century, a vast amount of information has been gained on the health effects of exposure to nuclear radiation (hereinafter referred to as radiation) and on technologies for protection against radiation and for the safety of nuclear power. Such comprehensive understanding derives from extensive research and development programmes and experience around the world. The results of this unprecedented effort have been regularly compiled by a unique international body — the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) — as well as by scientific and engineering professional organizations at both the national and international level.

On this basis, the so-called radiation protection and nuclear safety communities — a large number of scientists and technologists with practical experience and expertise in radiobiology, radiation and nuclear physics and engineering — have elaborated basic protection and safety objectives. The common objective of radiation protection and nuclear safety is to protect individuals, society, and the environment — including populations of species other than human — against adverse effects of radiation. Complementary objectives are to keep risks caused by radiation exposure as low as reasonably achievable and below prescribed constraints, and to prevent nuclear accidents and, should they occur, to mitigate their radiological consequences. The objectives encompass the protection and safety of all people exposed, or potentially exposed, to radiation because of nuclear power. They include ethical obligations to protect future generations and to preserve the natural state of the environment, and cover the entire cycle of activities required for nuclear power — from the acquisition of raw materials to the final disposal of wastes.

In order to achieve these objectives, a number of general and fundamental principles have been developed on an international level. A global *de facto* consensus on such principles has been achieved by internationally respected expert bodies: they notably include the long established International Commission on Radiological Protection (ICRP), which has issued recommendations on radiation protection since its inception in 1928, and the relatively new International Nuclear Safety Advisory Group (INSAG), which under the auspices of the IAEA has been formulating nuclear safety concepts since 1985. Such recommendations and concepts provide the basis for international safety standards, such as the IAEA/ILO/OECD-NEA/WHO Basic Safety Standards (BSS), the Nuclear Safety Standards of the IAEA Nuclear Safety Standards Advisory Group (NUSSAG), the Regulations for the Safe Transport of Radioactive Materials of the IAEA Standing Advisory Group on the Safe Transport of Radioactive Materials (SAGSTRAM), and the forthcoming waste management standards of the IAEA Waste Management Advisory Group (WAMAG).

The principles presented in the report are based mainly on ICRP and INSAG recommendations but also incorporate new developments

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that have recently been discussed at international forums on protection and safety.

The principles are interrelated and their enumeration does not imply any order of precedence.

The protection and safety philosophy embodied in the principles introduces a new ethic of individual and collective coexistence involving environmental pollutants, one that may well become indispensable in the face of growing global population and interdependence. The principles can — *mutatis mutandis* — also be applied to other potential hazards of the modern industrial world, including those caused by alternative means of generating energy.

Fundamental principles

First principle: Regulation by Governments. *Governments shall establish a legal framework and independent regulatory organizations for ensuring protection and safety in nuclear power.*

Governments shall bear the primary responsibility for adopting and continuing to use nuclear power and for controlling nuclear installations and the radiation exposure they may deliver. They shall establish a legal framework for protection and safety and provide the necessary infrastructure for the implementation of the legal requirements, including the allocation of sufficient resources. They shall also advocate the necessary research and development activities and foster the exchange and dissemination of relevant information. Governments shall institute the formal mechanisms for discharging such responsibilities by introducing legislation that establishes regulatory organizations and assigns the prime responsibility for protection and safety to the operators of nuclear installations. The regulatory organizations shall establish protection and safety norms, regulations, and rules and standards — including exclusions and exemptions — and provide for their enforcement. They shall institute formal systems for governmental registration and licensing, or other statutory means, and for surveillance, monitoring, review, verification and inspection of nuclear installations. They shall also take any enforcement actions as well as require feasible corrective actions by operators. The regulatory organizations shall act independently of the suppliers of nuclear installations and of their operators; the separation of the responsibilities of the regulatory organizations and those of other parties shall be clear, so that the regulators retain their independence as a protection and safety authority and are guarded from undue external influence. Governments are also expected to prescribe intervention to reduce pre-existing exposures due to previous events connected with nuclear power.

Second principle: Justification of nuclear power. *Nuclear power shall be justified in relation to alternative options for energy production.*

Nuclear power — like all alternative options for energy production — has detrimental effects, and these include adventitious radiation exposure of people. The adoption and continuation of a nuclear power programme shall be justified on the basis that it should produce sufficient benefit to the exposed individual or to society to counterbalance the radiation detriment it may cause, and that the net benefit should be greater than that for alternative options. The magnitude and likelihood of exposures expected from nuclear installations shall be explicitly taken into account in the justification process.

Third principle: Protection of individuals. *The exposure of individuals caused by nuclear power shall be limited.*

Nuclear power may cause adventitious radiation exposure of people and thus radiation risk attributable to the exposure. In order to ensure that no person be subject to an attributable risk that may be judged to be unacceptable, the magnitude and the likelihood of the exposure of any individual caused by nuclear power shall be limited. As each nuclear installation can contribute to the total magnitude and likelihood of the individual's exposure, the exposure due to each installation shall be constrained to ensure compliance with the limitation. Moreover, as some installations can release long-lived radioactive materials that move through the environment and may expose people distant from the installation and people of future generations, the limitation shall be ensured wherever and whenever the exposure is foreseen. In particular, in order to fulfil an ethical obligation to future generations, the cumulative exposure by the releases of radioactive materials into the environment caused by the continuation of nuclear power programmes shall be limited to a level judged to be acceptable at the time of the decision to release.

Fourth principle: Preservation of the environment. *Nuclear power shall not jeopardize the general natural state of the environment.*

Precautions shall be taken to limit any global environmental changes that could conceivably be brought about by nuclear power. The purpose shall be to ensure that the natural state of the environment is generally preserved within its normal variations and that the availability of natural resources needed for a sustainable development is not compromised.

Specifically, nuclear power produces radioactive byproducts and wastes that, in the long term, might not remain isolated from the regions of the earth's crust and the atmosphere occupied by life forms, i.e. from the biosphere. Therefore, the expected inflow rate of radioactive materials into the biosphere caused by the disposal of these byproducts and wastes should be a small fraction of the predicted inflow rate to the biosphere of comparably hazardous natural radioactive materials (which would either naturally enter the biosphere from the geosphere or be produced in the biosphere). Moreover, as local environmental concentrations of radioactive materials could affect populations of species in the biota, the inflow rate of such materials to the environment shall be limited to ensure that neither whole species be endangered nor imbalance be created among species.

Fifth principle: Optimization of protection and safety. *Nuclear installations shall be subject to the best protection and safety measures reasonably achievable under the prevailing circumstances.*

In order to reduce further the radiation risks due to any particular nuclear installation, it is necessary to consider how best to use resources for improving protection and safety. The preferred selection among the available protection and safety options shall be the optimum, so that the magnitude and likelihood of radiation exposures — wherever and whenever such exposures can be foreseen — and the number of people exposed, are all kept as low as reasonably achievable, economic and social factors being taken into account. The magnitude and likelihood of the individual exposures shall be constrained in order to reduce possible inequities among the exposed population.

Sixth Principle: Procedures of defense-in-depth. *Procedures of defense-in-depth shall be implemented to compensate for potential failures in protection and safety.*

To compensate for potential human and mechanical failures in the attainment of protection and safety, defense-in-depth procedures shall be implemented at all stages linking a nuclear installation to people's exposure. They must be centred on several levels of provisions; thus, a failure on one level should be compensated for or corrected by subsequent levels, providing a level of protection and safety greater than is achievable through any single provision. The procedures shall place principal emphasis on measures serving to prevent accidents by limiting the likelihood of sequences of events leading to exposure of people or to releases of radioactive materials to the environment. Further mitigatory measures, including procedures for managing potential accidents, for emergency preparedness and for subsequent remedial actions, shall be prepared and available to reduce substantially the effects of an accident.

Seventh Principle: Application of sound technical criteria. *Protection and safety shall be based on sound engineering andmanagement, quality assurance, trained and qualified personnel, comprehensive assessments, and lessons from experience and research.*

The siting, design, construction, commissioning, operation, maintenance, waste management, and decommissioning of nuclear installations shall be based on sound engineering, proven by testing and experience and reflected in approved codes and standards and other appropriately documented instruments, and on reliable managerial and organizational features, with the aim of ensuring protection and safety throughout the life cycle of the installation. A quality assurance system of planned and systematic actions shall provide adequate confidence that the specified requirements are satisfied. All personnel on whom protection and safety depend shall understand their responsibilities and be trained and qualified to perform their duties according to defined procedures; nevertheless, the possibility of human error shall be considered as one of the primary contributors to accidents, and provisions shall be made to reduce this contribution and to provide means for detecting and correcting or compensating for it. Well-documented and independently reviewed assessments shall be conducted at the different stages in the life of the nuclear installation. Organizations concerned shall ensure that due recognition be given to future developments in technical criteria; that the results of research relevant to protection and safety be exchanged, reviewed, analysed and applied; and that lessons from experience be learned and acted upon.

Eighth Principle: Attainment of a protection and safety culture. *An established protection and safety culture shall govern the actions and interactions of all persons and organizations engaged in activities connected with nuclear power.*

Essential elements for the achievement of protection and safety in activities connected with nuclear power are the personal dedication and accountability of all those who are engaged in them, particularly of those at the corporate and management level. Consequently, a protection and safety culture shall be inculcated, including an all pervading safety consciousness on the part of the persons concerned, which requires an inherently questioning attitude, the prevention of complacency, a

Definition of terms

The term ***nuclear power*** is used to mean the practice of generating electricity by nuclear means. It includes any related activity, such as the operation of nuclear installations, that may increase the background exposure of people to radiation. It encompasses the full cycle of activities needed for the practice, from the extraction of the required raw materials for the nuclear fuel to the final disposal of radioactive wastes.

The term ***nuclear installation*** is used to mean any physical entity within the nuclear power practice that may cause radiation exposure by emitting ionizing radiation or releasing radioactive materials. Examples of nuclear installations are nuclear power plants and repositories for radioactive wastes.

The term ***radiation exposure*** is used to mean being subject to ionizing radiation; it specifically refers to irradiation of persons, either from outside the body or due to radioactive materials incorporated into the body, and is measured by radiological quantities such as absorbed dose, equivalent dose, or effective dose. The radiation exposure due to nuclear power is not intended but adventitious (i.e. collateral to the purpose).

The terms ***protection and safety*** are used to mean the quality of nuclear power and nuclear installations of being unlikely to cause hurt, danger or injury due to radiation exposure and, therefore, not liable to deliver unacceptable radiation risk; the term also applies to the means for achieving protection and safety, such as various procedures and devices for keeping people's risks as low as they can reasonably be and within prescribed constraints, for preventing accidents, and for mitigating the consequences of accidents — should they occur. The term encompasses the technical disciplines of nuclear safety and radiological protection (including radioactive waste management and disposal).

The term ***operator*** is used to mean a legal person or legal entity with recognized rights and duties for operating a nuclear installation; the term applies to any individual, organization corporation, partnership, firm, association, trust, estate, public or private institution, group, or any political or administrative entity, who or which has accepted possession of a nuclear installation and is in complete charge of it, with full responsibility and commensurate authority for its operation in approved activities.

The term ***intervention*** is used to mean any action intended to decrease exposures due to inherited *de facto* situations connected with nuclear power such as radioactive residues from previous events. Intervention can be undertaken by altering the network of the pre-existing causes of exposure, exposure pathways and exposed individuals, e.g. by eliminating the causes of the exposure, modifying the existing exposure pathways, or changing people's habits, circumstances or actions so as to preclude their exposure.

The term ***magnitude*** of exposure is used to mean the amount of the quantity measuring the exposure (e.g. dose); the term ***likelihood*** of exposure is used to mean probability of occurrence of the exposure, i.e. the degree of belief that the exposure will actually occur, under the condition that reasonable assumptions have been made on the basis of the available information.

The term radiation ***risk*** is used to mean a multidimensional quantity expressing hazard, danger or chance of harmful or injurious consequences that can be attributed to the radiation exposure. It relates to objective quantities such as the probability that specific deleterious consequences may arise and the magnitude and character of such consequences; it may also include subjective considerations such as familiarity with, and willingness or voluntariness in incurring, the hazard and knowledge of the consequences.

The term ***individual*** is used to mean an idealized human being representative of the group of persons expected to receive the highest radiation exposures, wherever this group may be located and whenever the exposure may occur; this group being reasonably homogeneous with respect to factors that affect the exposures of its members.

The term ***defense-in-depth*** procedures is used to mean a system of protection and safety provisions applied at all stages linking a nuclear installation to people's exposure whereby all related activities, whether organizational, behavioural or equipment related, are subject to layers of overlapping provisions, so that if a failure should occur it would be compensated for or corrected.

The term ***protection and safety culture*** is used to mean that assembly of characteristics and attitudes in persons and organizations which establishes that, as an overriding priority, protection and safety issues receive the attention warranted by their significance.

The term ***international regime*** is used to mean an international system aimed at the global harmonization of radiation protection and nuclear safety whereby States retain prime responsibility, preeminence, and hegemony in its regulation.

commitment to excellence, and the fostering of both personal accountability and corporate self-regulation.

Ninth Principle: Responsibility of operators. *The operator of a nuclear installation shall bear the ultimate responsibility for protection and safety.*

The ultimate responsibility for protection and safety shall rest with the operator of a nuclear installation and shall not be diluted by the activities and responsibilities of its designers, manufacturers, suppliers or constructors, or of the competent regulatory authorities. Nevertheless, the designers, manufacturers, suppliers, and constructors of the installation shall be required as a minimum to provide a sound design and equipment that meets its specifications in terms of both engineering detail and performance of the intended function, and complies with quality standards commensurate with the protection and safety significance of components or systems. The operator shall be responsible for specifying and ensuring that the design and construction of the installation meet the relevant protection and safety requirements, and for establishing and maintaining procedures, arrangements, and a competent and fully trained staff in order to ensure the safe operation of the installation under all conditions during its operative life. The operator shall also establish a policy for adherence to protection and safety requirements and procedures, and ensure that responsibilities are well-defined and documented and that protection and safety-related resources and facilities are in place.

Tenth Principle: Reduction of de facto exposures. *Radiation exposure due to previous events connected with nuclear power should, wherever justified, be reduced by intervention*

People may be subject to radiation exposure due to inherited, *de facto* situations. (*De facto* exposures connected with nuclear power are those due to radioactive residues from previous events, such as contaminations from old accidents.) In order to reduce the magnitude and likelihood of such exposures, governmental organizations should undertake protective measures by means of intervention, provided that the proposed intervention does more good than harm and that its form, scale, and duration are optimized so that they may be regarded as the most appropriate under the prevailing economic and social conditions. Intervention includes actions for eliminating the causes of the exposure, modifying the existing exposure pathways, or changing people's habits, circumstances or actions so as to preclude their exposure.

Epilogue

In September 1991, the International Conference on the Safety of Nuclear Power: Strategy for the Future, in Vienna, declared in its final document that "there is a need to consider an integrated international approach to all aspects of nuclear safety ...". At the same time, the 35th Regular Session of the IAEA General Conference — while considering measures to strengthen international co-operation in matters relating to nuclear safety and radiological protection — *inter alia* noted the potential value of approaches for promoting an international regime, reaffirmed the vital necessity of strengthening international co-operation, and stressed the need to consider a harmonized international approach.

The time seems ripe for making a proposal that may eventually evolve into a new fundamental principle of radiation protection and nuclear safety, namely:

The institution of an international regime to support a globally harmonized approach to all aspects of radiation and nuclear safety.

An international convention can be the formal vehicle for such a regime and for providing a *de jure* enforcement of the fundamental principles of protection and safety for nuclear power.❐

Cruas nuclear power plant in southeastern France. (Credit: EdF)