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NUCLEAR ACCIDENT
KNOWLEDGE TAXONOMY

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The Agency's Statute was approved on 23 October 1956 by the Conference on the Statute of the IAEA held at United Nations Headquarters, New York; it entered into force on 29 July 1957. The Headquarters of the Agency are situated in Vienna. Its principal objective is "to accelerate and enlarge the contribution of atomic energy to peace, health and prosperity throughout the world''.

IAEA NUCLEAR ENERGY SERIES No. NG-T-6.8

NUCLEAR ACCIDENT KNOWLEDGE TAXONOMY

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FOREWORD

One of the IAEA's statutory objectives is to "seek to accelerate and enlarge the contribution of atomic energy to peace, health and prosperity throughout the world." One way this objective is achieved is through the publication of a range of technical series. Two of these are the IAEA Nuclear Energy Series and the IAEA Safety Standards Series.

According to Article III.A.6 of the IAEA Statute, the safety standards establish "standards of safety for protection of health and minimization of danger to life and property". The safety standards include the Safety Fundamentals, Safety Requirements and Safety Guides. These standards are written primarily in a regulatory style, and are binding on the IAEA for its own programmes. The principal users are the regulatory bodies in Member States and other national authorities.

The IAEA Nuclear Energy Series comprises reports designed to encourage and assist R&D on, and application of, nuclear energy for peaceful uses. This includes practical examples to be used by owners and operators of utilities in Member States, implementing organizations, academia, and government officials, among others. This information is presented in guides, reports on technology status and advances, and best practices for peaceful uses of nuclear energy based on inputs from international experts. The IAEA Nuclear Energy Series complements the IAEA Safety Standards Series.

During over 14,700 cumulative reactor years of commercial operation in 32 countries, there have been three major accidents at nuclear power plants. These accidents aroused extensive concerns and resulted in a call for concerted global efforts to further enhance nuclear safety. In an effort to continually improve safety at nuclear power plants, the international nuclear community has incorporated lessons learned from these accidents into safety improvement programmes. The Fukushima Daiichi accident highlighted once more the need to access knowledge and experience from previous accidents, and making best use of that knowledge has risen high on the agenda of Member States. Preserving the knowledge of nuclear accidents, and organizing it into a usable and easily accessible form is a high priority for national authorities — not only in the countries where accidents have happened but in all Member States with active nuclear power programmes. This publication focuses on major nuclear accidents which involved fuel melting. The taxonomy described is not meant to serve as a template for incident reporting in nuclear power plants or fuel cycle facilities. For that, readers are directed to other IAEA publications on the international reporting system for operating experience.

This publication has been written at the request of Member States, with the main objective to create a knowledge based tool for the organization of data, information and knowledge from nuclear accidents. The knowledge taxonomy for nuclear accidents has been developed using the insights of key international experts who directly participated in the response and follow-up to the three major accidents: the Three Mile Island accident, the Chernobyl accident and the Fukushima Daiichi accident.

The IAEA is grateful to all participants who contributed to the drafting and review of this publication. The IAEA officer responsible for this publication was T. Karseka-Yanev of the Division of Energy Planning and Nuclear Information and Knowledge.

EDITORIAL NOTE

CONTENTS

1. INTRODUCTION

1.1. BACKGROUND

The global nuclear industry has experienced three major nuclear accidents, which have strongly influenced the nuclear industry[1], each with different internal damage to the reactor core, different levels of radioactive release to the environment and different actions taken to deal with the emergency: the Three Mile Island accident (1979), the Chernobyl accident (1986) and the Fukushima Daiichi accident (2011). Each of the three accidents had its own causes and consequences. Some of which were very specific in terms of the reactor design, the operator's actions or the emergency measures taken; while other factors, such as evacuation, protection of the public and follow-up measures, were common for all three accidents. Lessons learned have been discussed and findings have been formally published. However, much useful data, information and knowledge have been produced and stored locally, while much data have never been structured or shared with the broader community. Although many historical records and documents exist, they have not been collected and stored in a structured format which could be accessed and searched.

Key factors contributing to the lack of a systematic approach to extracting the lessons from previous accidents include the fact that the nuclear accidents happened in different countries and at different stages of development of information management technology and national and global communication systems. While records from the Three Mile Island accident have been largely digitized and made available [1], much of the Chernobyl information is still stored in paper records or specialized archives and is not directly available or accessible. In both the Three Mile Island and Chernobyl accidents, the opinions, advice and specialized (experiential and practical) knowledge and contextual information from experts and participants in the accident, to a great extent, has either not been recorded or has been lost, as people move on, retire or pass away.

Important lessons learned include necessary improvements in designs, operating practice, training, maintenance, and emergency preparedness and response, but all with the aim to avoid recurrences or to minimize the consequences of a recurrence. In the absence of a systematic structuring and cataloguing of lessons learned from each accident, some lessons may not have been ubiquitously recognized, captured, understood, disseminated or acted upon.

The accident at the Fukushima Daiichi nuclear power plant, following the Great East Japan Earthquake on 11 March 2011 and the resulting tsunami, was the clearest demonstration that, in such a critical situation, the time available for decision making may be too short. Therefore, an adequate capacity for an efficient response should be in place at the operating organization at the local, regional and national levels [2]. The availability of information or a knowledge organization system[2] that integrates lessons learned from previous experience are critical components of an emergency management system required for an effective preparedness and response. Access to lessons learned from previous accidents is even more important in the post-accident period, when important decisions need to be made for assessing the consequences and implementing further measures, as well as in identifying possible areas of improvement in the regulatory processes.

Since 2005, the IAEA has developed significant experience in preserving nuclear knowledge. Modern technologies for preserving and maintaining critical knowledge, including nuclear information in digital form, as well as the capture of 'tacit' knowledge of experts through multimedia and codification efforts, have been utilized [3]. A number of methods and routines have been developed for capturing and visualizing nuclear knowledge using, for example, video recordings of expert interviews, knowledge mapping technologies, collaborative databases and repositories, information management systems and knowledge organization systems based on taxonomies.

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[1] There have been about 30 incidents and accidents since the first accident was recorded at Chalk River, Canada, in 1952. Primarily, the three most serious and well documented accidents were used for the development of the nuclear accident knowledge taxonomy. However, the taxonomy is applicable and can be used for preservation of all knowledge of nuclear power or other radiological accidents. The taxonomy is not meant to replace any structured incident reporting systems which exist at the national and international level; however, it could complement them.

[2] A system that helps to organize and eventually retain information and knowledge based on classification schemes, taxonomies, thesauri, topic maps and ontologies.

For example, the Institute for Energy and Transport (IET) of the Joint Research Centre (JRC) recognizes the importance of preserving knowledge and experience of nuclear accidents. Within the Practical Arrangement between the IAEA and the IET, signed on 27 October 2009, closer cooperation in the development and sharing of multimedia material for nuclear knowledge preservation, dissemination and capacity building is ongoing.

The development of safe, reliable nuclear power generation depends on the knowledge of designers, constructors and operators, as well as those who initiate and supervise the development of nuclear power in their countries, which is the key ingredient for national programmes to be sustainable [4].

Since the start of the commercial use of nuclear technology, there have been several nuclear accidents that resulted in a release of radioactive material into the environment and thus, in the exposure of workers, including emergency workers and the public. The global nuclear sector has been continually learning from these events of the past and has undertaken significant improvements in regulation and management of nuclear technology, as well as preparedness and response for nuclear and radiological emergencies [2, 5, 6]. However, nuclear regulation is the responsibility of each Member State. This presents an ongoing challenge both for States with existing nuclear installations and for newcomer States to ensure they establish and maintain the appropriate competencies and knowledge for safe and sustainable regulation and management of nuclear facilities. This also includes the awareness of lessons learned from nuclear accidents and methods for mitigating potential consequences.

Although there is currently a large amount of information and technical resources on nuclear accidents which can be found on-line, it is unstructured and difficult to use to learn from past experience. Consequently, it is essential to create an effective means to organize information on nuclear accidents which has been collected and to permit its easy access. As a means to achieving this goal, this publication proposes and defines the first version of the IAEA Nuclear Accident Knowledge Taxonomy (NAKT), which is based on the allocation of specific topics and their key words and represents a hierarchical structure in which knowledge on nuclear power accidents is categorized and easy to find [7]. An approach to creating a repository to manage this information, referred to as the Nuclear Accident Knowledge Organization System (NAKOS), is also described.

The IAEA has taken the initiative to coordinate efforts of Member States in the preservation of nuclear accident knowledge. In the framework of this initiative, the IAEA intends to create an international portal for knowledge on nuclear accidents by unifying common topics related to nuclear accidents, as well as creating a unified format and comprehensiveness of preserved material to cover all aspects of nuclear accidents and experience available.

Under the IAEA Action Plan on Nuclear Safety[3], the IAEA was requested to assist Member States in enhancing transparency and effectiveness of communication among operators, regulators and various international organizations, and in supporting wide dissemination of safety related technical and technological information enhancing nuclear safety [8]. The IAEA was further asked to analyse and preserve lessons learned from the Fukushima Daiichi accident, as well as from other major accidents and radiological events in the past.

NAKT is a core element of NAKOS. It is a structure of terms which is meant to help in both organizing and searching for required information. NAKOS is an integrated solution for knowledge preservation, retrieval and management developed for, and applied to, nuclear power plant accidents. It covers experience captured on serious nuclear accidents in States which experienced the accidents. It is a tool for organizing the existing information and knowledge in a structured way based on a systematic and continuing approach.

NAKT was developed by the IAEA in close cooperation with Member States' international experts who were involved in at least one of the three major nuclear accidents and personally participated in mitigating its consequences for people and the environment.

The IAEA organized two consultancy meetings and one technical meeting with an international team of experts in accident knowledge preservation. It was recognized that the creation of NAKT is an urgent task for the international nuclear community, and it will help to address the loss of knowledge and to avoid repeating the same mistakes. As an example, the Japanese Government has initiated a programme to implement the taxonomy provided in this publication and will evaluate a trial of the taxonomy's effectiveness for structuring and organizing information.

[3] The Action Plan was approved by the IAEA Board of Governors on 13 September 2011, as endorsed by the IAEA General Conference during its 55th regular session on 22 September 2011.

1.2. OBJECTIVE

The objective of this publication is:

(a) To develop a specialized taxonomy on nuclear accidents, which can be used by the IAEA in its own work and by organizations and institutes in Member States;
(b) To provide a description of NAKOS features and the methodology to organize knowledge in this area;
(c) To provide examples of possible applications of NAKT nationally and internationally.

1.3. SCOPE

This publication presents the basis for the international knowledge organization system on nuclear accidents[4], along with the computer software requirements for digital preservation. The following main issues are addressed in this publication:

(a) Description of NAKOS[5];
(b) Basic requirements and methodology for NAKT;
(c) Approach for categorizing nuclear accident knowledge;
(d) Implementation of NAKT and NAKOS.

It should be noted that the taxonomy has been developed for a variety of users:

— Governments;
— Regulatory bodies;
— Emergency response organizations;
— Designers;
— Operators;
— Technical support organizations.

The taxonomy and system requirements described are addressed primarily to IT specialists and information and knowledge retention experts in the types of organization listed above. The taxonomy and system requirements described are applicable for States with a nuclear power programme and States embarking on one. Guidance provided here, describing good practices, represents expert opinion but does not constitute recommendations made on the basis of a consensus of Member States.

1.4. STRUCTURE

This publication provides practical information on the ways to organize knowledge of nuclear accidents. In addition to the introduction in Section 1, Section 2 includes information about the concept of a knowledge organization system, its basic principles and the main technical requirements for implementing NAKT. Section 3 provides information about standards and basic principles used for developing NAKT, and introduces the taxonomy approach and boundary conditions for its application. Section 3 also presents NAKT with relevant synonyms. Section 4 contains several possible applications for NAKT. Section 5 summarizes the conclusions.

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[4] The taxonomy primarily, but not exclusively, focuses on structuring documentation available for facilities such as nuclear power plants which fall in the emergency preparedness category I [2].

[5] When made available, appropriate on-line support will be provided for the users of NAKOS.

2. NUCLEAR ACCIDENT KNOWLEDGE ORGANIZATION SYSTEM

Knowledge and information in the nuclear industry field is often available to users in a very fragmented and unstructured manner. The IAEA's implementation of NAKOS based on NAKT is an example of the approach to implement the taxonomy with a consistent methodology for handling large volumes of data, without losing an overview of different nuclear accident aspects and the entire spectrum of lessons learned from different accidents in different countries.

2.1. CONCEPT

Figure 1 contains the main elements which comprise NAKOS:

— Web portal: A web site that functions as a point of access to information, and the principal user interface for NAKOS. It also includes documents received by the IAEA from Member States, as well as IAEA publications on nuclear accidents.
— Rules: The logic used to create taxonomy queries. These rules take into account features of the system in terms of the professional vocabulary, as well as forming logical boundaries for similar terms, homonyms and morphological rules with the help of logic operators.
— Target users: The specific groups of people within a nuclear organization which actively use accident related material in their work. Target users work with the system through a user interface, which allows easy access to the desired information.
— Software platform: This includes a search engine and integrates all parts of the knowledge organization system. It provides tools for creating collections from repositories, manages them through queries or complex query editors and retrieves data with the search engine.
— Repository: Also known as the collection, this is an array of unstructured data or metadata on one subject. Usage of appropriate software allows retrieval of explicit information from the repository. The collection is formed by using the full text data or metadata indexing.
— Vocabulary: The terms from applicable glossaries and documents used to develop the taxonomy. For NAKT, the IAEA Safety Glossary [9] was primarily utilized for creating 'controlled vocabulary'[6]. Other specific terms used in the taxonomy are consistent with Refs [10, 11].
— Taxonomy: This is the core facility implemented in the system for managing and retrieving precise information. It is a classification scheme and represents the main structure for knowledge organization system repositories.

[6] This is an alphabetic list of terms defined as permissible for a specific indexing project. An example would be the Library of Congress Subject Headings, a compendium of documents used by the US Library of Congress to define the terms that may be used to index its collections.

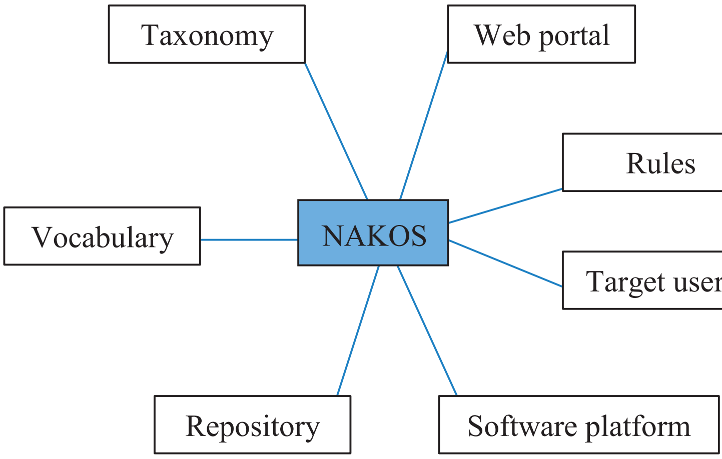

FIG. 1. NAKOS concept components.

Figure 2 represents the web portal development steps. It begins with developing (or defining) the software platform, and concludes with the point of taxonomy and logic implementation into the system.

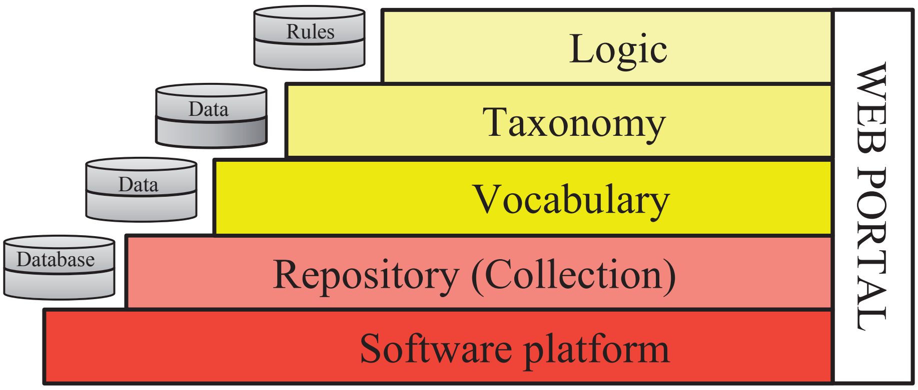

FIG. 2. NAKOS development steps.

2.2. BASIC PRINCIPLES

NAKOS is based on the principle of utilizing an electronic database, since that is the primary option that offers the capability for a rapid and effective search of the required information to support nuclear knowledge management. The following sections describe the main principles and parts of the collaborative tools system. These tools provide a wide range of possibilities for interaction of subject matter experts with NAKOS.

2.2.1. Nuclear Accident Knowledge Organization System Portal

The NAKOS portal is an automated system for retrieving information from an international database which combines information from the various Member States and the IAEA concerning nuclear accidents and their consequences [12]. The portal is a facility, or interface, usually Internet based, to provide a means for users to gain convenient access to NAKOS for queries and input, as required.

The information stored in the database includes various word indexes, an internal documents table containing document field information and pointers to the actual files. The documents in the NAKOS portal originate from the following sources:

— INIS[7] subset for Chernobyl, Fukushima Daiichi and the Three Mile Island accidents, including abstracts and full text;
— IAEA on-line publications[8] (full text);
— Publicly available reports from national authorities in IAEA Member States and other relevant organizations.

The purpose of the NAKOS portal is to ensure that all users have prompt and easy access to information on nuclear accidents, whenever they require it, and that it may be accessed from anywhere in a local web based environment [13], without installing any additional software, and without any concerns of local computer management and data maintenance.

The NAKOS portal provides a wide range of capabilities to search for information, using:

— Taxonomy;
— Simple and free text queries;
— Queries with Boolean logic operators (e.g. “circulation” <AND> “pump”);
— Previously saved queries.

2.2.2. Nuclear Accident Knowledge Taxonomy

NAKT is a tool to search for relevant information on a broad range of topics from the status of nuclear installations and policies prior to an accident to lessons learned and practical experience in addressing the consequences of nuclear accidents. It has a hierarchical topical structure of information about nuclear accident knowledge.[9] This tool was made for rapid access to an exponentially growing amount of data and information on the subject. The taxonomy development process and its features are described in Section 3.

2.2.3. Software

2.2.3.1. Components

The basic software which can be used to develop or host NAKOS should contain the following components:

(a) Indexer: A tool which is used to create and manage full text sources.
(b) Search engine: A tool which retrieves relevant documents from collections by use of queries.
(c) Query editor: A tool for building complex queries for the search engine.
(d) User interface with authority control[10] functionality.

The interaction of the tools provided offers a collaborative software system.

2.2.3.2. Indexer

The indexer collects and processes full text documents. It extracts a list of keywords from documents, publications and other metadata and gathers them into a table. This table is stored in a collection file which can be managed by the search engine.

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[7] The International Nuclear Information System (INIS) contains one of the world largest collections of published information on the peaceful uses of nuclear science and technology.

[8] IAEA safety standards and other relevant publications, such as the Emergency Preparedness and Response Series, IAEA publications on accident response and the IAEA Nuclear Energy Series.

[9] Depending on the software parameters, the taxonomy can be modified and used as a thesaurus or ontology.

[10] Standardized rules governing terms permitted for use as index entries.

The collection file (or repository) optimizes the performance and speed of finding documents and publications. Without preliminary indexing, the search engine would be required to scan every document each time a search is performed, which would require a much longer response time and unnecessary high computer performance.

2.2.3.3. Search engine

The search engine uses queries to retrieve relevant information from the existing collections of indexed documents. The following properties are used to evaluate search engine performance:

— Precision (p): Measures how well the search engine retrieves the relevant documents. Precision can be calculated as a ratio of the relevant and useful retrieved documents to the sum of relevant and irrelevant documents returned in the particular query.
— Recall (r): Measures how well the search engine retrieves all of the relevant documents from the database as a whole. In mathematical terms, this would be the ratio of the number of relevant and useful documents retrieved to the number of relevant documents in the database.

In general, search engine functionality should include:

— A percentage ratings of found documents by relevance to a query;
— Automated clustering by common concepts or topics;
— Automatically generated annotation;
— A presentation of query results across time in a chart or graph;
— Multilingual searchs;
— The capability to utilize free text to formulate queries.

2.2.3.4. Query editor

The query editor is a tool which allows the user to create complex queries. These queries can be presented in different forms, but the most common query type is the nested or hierarchical structure. One branch of the structure may be a so called topic tree.

2.3. NUCLEAR ACCIDENT KNOWLEDGE ORGANIZATION SYSTEM REQUIREMENTS

The requirements for NAKOS are:

(a) A search of documents by following down along a chosen branch level structure.
(b) A multivector search of documents using key words. For example, the following attributes may be used as key words: topic, reactor facility, author, country, year and topical key words.
(c) Creating various search options by the combination of attributes:
  — A search of documents containing a certain combination of attributes within the framework of one document. This means that all documents will be selected whose metadata or information card matches all specified combinations of attributes (logic combination <AND> for specified attributes);
  — The document selection contains at least one out of the attributes whose metadata or information card matches the description of the document (logic combination <OR> for specified attributes);
  — A combined search is applied for using a logic combination <AND/OR> for specified attributes. In this case, the information cards or metadata, which contain all attributes, specified with logic condition <AND> and at least one out of the other attributes specified with logic condition <OR> will be chosen;
(d) A search of both the NAKOS document repository and some selected sections and topics.
(e) A sequential search (with narrowing or changing the search vector), allowing for multiple, sequential search iterations with a constant narrowing of the list of selected documents.
(f) If necessary, saving the list of documents resulting from a search in a separate temporary file in NAKOS.

(g) Direct access to the information card of any document from the list of those selected as a result of a search, in case information cards are used.
(h) Access to the entire NAKOS section from which a particular document was selected by the user.
(i) Consolidation of various files containing results of searches into a common file.
(j) An option for a controlled access and diverse access permissions.

3. NUCLEAR ACCIDENT KNOWLEDGE TAXONOMY

In the knowledge management practice, taxonomy is applied for improving the use of large repositories of information and for making them easier to search. In order to organize a collection of documents on nuclear accidents and produced by different working groups in different organizations and in different countries, it would be best to classify them uniformly to facilitate retrieval. Otherwise, if content can only be retrieved in the language of the author, or by any possible synonymous term, retrieval becomes lengthier and more problematic. Building a list of terms that would control the way the documents are classified or indexed is the first step in bringing efficiency to searching. The net content of these documents will help to determine the uniform terminology that would be selected, and simultaneously, where cross-references belong.

Taxonomies are specialized indexes of terms which guide users to the information they are looking for. What distinguishes a taxonomy from an index is the controls or limits on permitted terms coupled with the possibility for relationships among the terms in the list. The rapid development of information technology and the need for precise and fast retrieval of information have made the application of taxonomies in the current information management systems almost obligatory.

In this publication, taxonomy for nuclear accidents is defined with special emphasis on when and where it can be useful and how it can be implemented in a knowledge organization system. It serves as a classification scheme and a knowledge map which allows knowledge managers further enlargement, maintenance and application of the taxonomy.

3.1. GENERAL PARAMETERS

NAKT was developed to enhance system search capabilities and to integrate knowledge with a variety of nuclear specializations and backgrounds. The taxonomy should be developed accordingly to create the ability:

(a) To create a hierarchy of terms and make a sample of the form “term + all child terms”[11];
(b) To navigate easily;
(c) To expand terms;
(d) To open filters in a drop-down list;
(e) To change the name of the term, and the changes will affect all content;
(f) To assign synonyms to each term;
(g) To shift a term within the taxonomy or indicate relationships between terms;
(h) To translate terms into other languages;
(i) To assign specific roles or rights to edit terms.

The structure should include categories and terms which are significant and helpful for finding and analysing information and facts related to reasons, evolution and consequences of nuclear accidents. The structure should be comprehensive and provide a common environment for different user groups.

[11] Child terms are a subgroup of parent terms and are lower down in the hierarchy.

Table 1 provides the first concept level and defines branches of the topic tree structure. It also describes integrated taxonomy parameters, along with the proposed index depth (i.e. the number of levels from the main parent term to the main child term) and the number of terms. It should be noted that Table 1 does not include synonyms, related terms or antonyms that can be used to build queries.

TABLE 1. TAXONOMY PARAMETERS

Topic	Max. depth	Terms
Legal and governmental framework	4	23
Nuclear installation status	5	98
Accident management	4	20
Emergency preparedness and response	4	99
Scientific and technical support	4	33
Accident consequences	4	53
Total		326

3.2. NUCLEAR ACCIDENT KNOWLEDGE TAXONOMY DEVELOPMENT

For viewing the whole taxonomy development process, ISO/IEC/IEEE 15288:2015 [14] was applied. This is an international standard which has been created to establish a common framework for system life cycle stages. According to ISO/IEC/IEEE 15288:2015 [14], any system or object of interest has a definite life cycle that consists of multiple stages through which the system passes during its lifetime.[12] These stages are presented on the V model life cycle in Fig. 3.

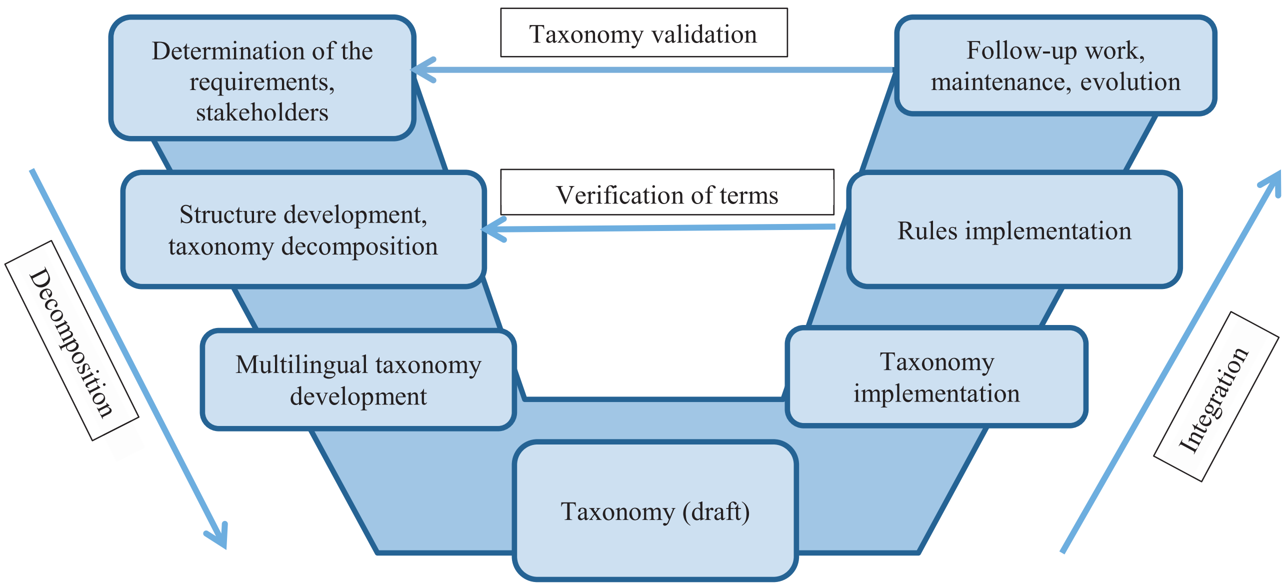

FIG. 3. Development phases for NAKOS and its taxonomy.

[12] See http://productrealize.ir/library/ISOIEC%20JTC%201SC%207WG%207-2002.pdf

This model reflects how the requirements for the NAKT transformation would be applied to the effective product, and it can be used to reproduce the same product where necessary. Thus, the development of NAKOS and its taxonomy consists of the phases outlined in Fig. 3.

Terminology, as well as characteristics and descriptions of circumstances, change from time to time, and as a result the taxonomy should also be continually evolving and maintained by the system developer. In this case, it is important to reconnect and liaise with subject matter experts for periodic taxonomy verification and validation.

3.3. DESCRIPTION OF THE NUCLEAR ACCIDENT KNOWLEDGE TAXONOMY APPROACH

The taxonomy begins with broad, general major categories or branches, and proceeds to deeper, more detailed descriptions and their details. This method may be used to provide as much depth as content requires. The nuclear accident knowledge domain is a very broad subject, which means that tagged keywords should be commonly understood and used (or supported by additional clarifying synonyms) by experts and parties involved to provide the most relevant search results. Vocabulary and terms used in the IAEA publications, including the IAEA Safety Standards Series and the IAEA Safety Glossary [9] were applied for developing NAKT as the main internationally recognized terminology standard. Afterwards, the taxonomy was enriched by other terms and synonyms from papers written on experience gained after nuclear accidents. The IAEA publications related to the subject are available in NAKOS for search and analyses. An overview of the NAKT key branches can be found in Fig. 4.

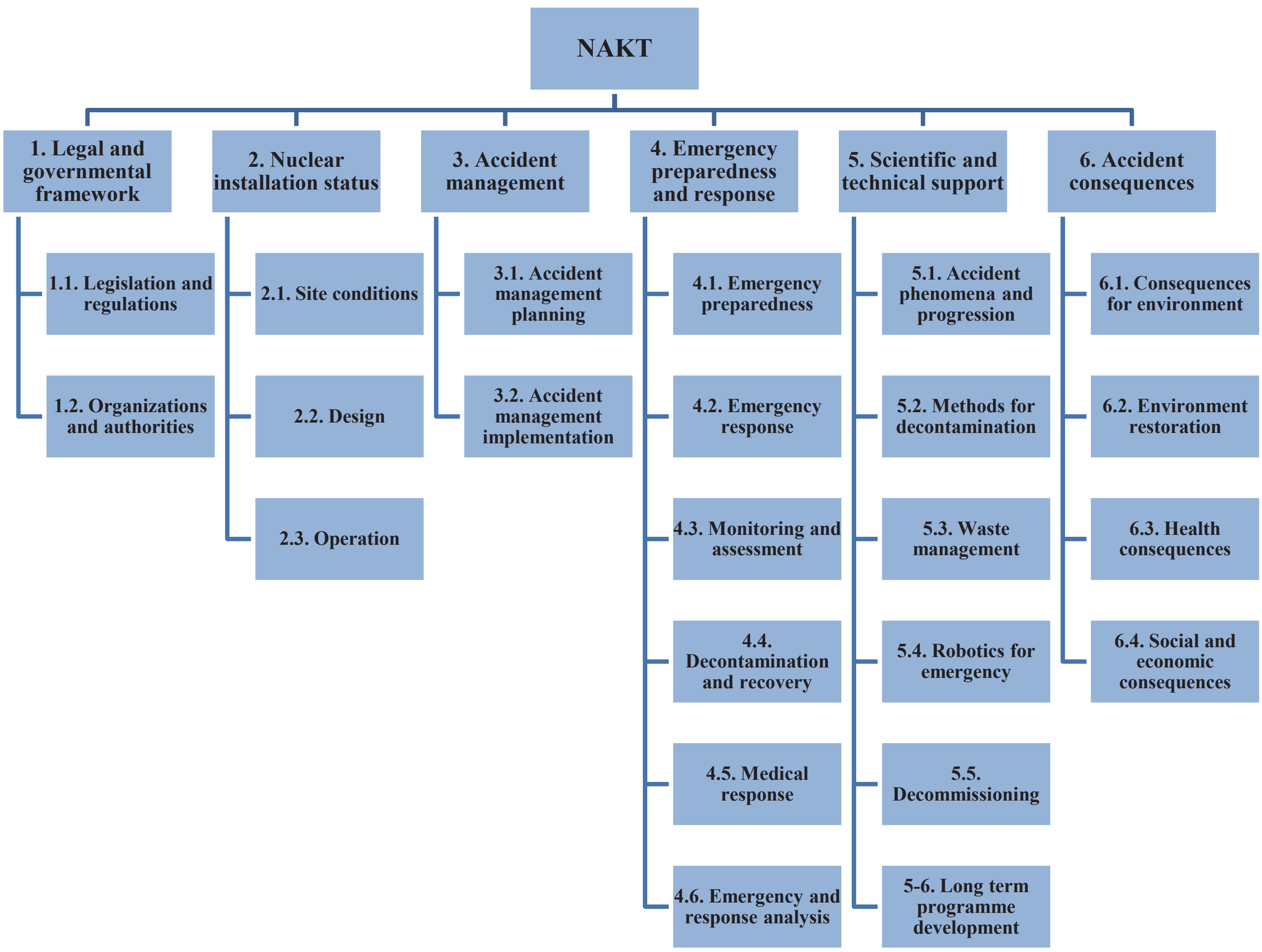

FIG. 4. Schematic representation of the two upper levels of NAKT branches.

3.3.1. Legal and governmental framework

The taxonomy branch 1 contains terms related to the overall nuclear governing and regulatory system of a place (country and region) where the accident happened. It includes conventions, laws, regulations, governing structures and instructions applied for normal and emergency operations. The documents and explanations in this topic could help to analyse and understand the root causes of an accident which are hidden in the system or boundary conditions (see Table 2) [15].

TABLE 2. TAXONOMY BRANCH 1: LEGAL AND GOVERNMENTAL FRAMEWORK

Subsection	Content
1.1. Legislation and regulations	Information about a constitution, laws, decrees and regulations which were present in a country prior to the accident, as well as ratified international conventions.
1.2. Organizations and authorities	Information on the operating organization, response organizations, the regulatory body, as well as other stakeholders which are responsible for emergency preparedness and are involved in response to a nuclear emergency. The topic also contains terms which reflect interfaces, coordination and communication between different parties and organizations during the emergency.

3.3.2. Nuclear installation status

The taxonomy branch 2 contains topics on the design of nuclear installations which suffered nuclear accidents, as well as topics which help to find information on the site conditions and the most relevant information on the operational practices and workflows in the operating organization (see Table 3).

TABLE 3. TAXONOMY BRANCH 2: NUCLEAR INSTALLATION STATUS

Subsection	Content
2.1. Site conditions	Relevant terms on describing usual or extraordinary nuclear power plant site conditions before the accident occurred. It includes natural and human events, as well as information about the region, demographics and available infrastructure.
2.2. Design	List of basic design features, reactor components or critical systems, which under certain conditions could have been critical for how the accident progressed.
2.3. Operation	Information on the operating organization. It includes its structure, staffing, personnel training and operational procedures. It includes information about the status of fresh and spent fuel on the site before a given accident, as well as about radioactive waste at the plant [16].

3.3.3. Accident management

The taxonomy branch 3 collects information (knowledge) related to the set of actions during the evolution of a given accident (see Table 4):

(a) To prevent the escalation of the event into a severe accident;
(b) To mitigate the consequences of a severe accident;
(c) To achieve a long term, safe and stable state.

TABLE 4. TAXONOMY BRANCH 3: ACCIDENT MANAGEMENT

Subsection	Content
3.1. Accident management planning	Relevant documents for the accident management strategy employed by a given operating organization. It involves results or assessments of available safety analysis of a given installation, which includes assessments of external and internal events. An initial accident management strategy, including responsibilities assigned and instructions for personnel training and drills on accident management, can be found here.
3.2. Accident management implementation	Description of the actions which are needed, or were taken, to recover the cooling systems, to confine radiation and to perform other critical functions in a nuclear installation under accident conditions.

3.3.4. Emergency preparedness and response

The taxonomy branch 4 focuses on preparedness for, and response to, a nuclear emergency involving fuel damage in the core or the spent fuel pool of a nuclear power plant. Its structure considers IAEA safety standards in emergency preparedness and response [2, 5, 6] and helps to navigate through information which describes the level of preparedness of a nuclear installation where such an emergency happened and the emergency response actions taken. It deals with the preparedness and response to the emergency beyond the accident management (see Table 5).

TABLE 5. TAXONOMY BRANCH 4: EMERGENCY PREPAREDNESS AND RESPONSE

Subsection	Content
4.1. Emergency preparedness	Key terms which address methodology and criteria for hazard assessment for emergency preparedness and response and for the development of the protection strategy, including results of the hazard assessment and the protection strategy in place prior to the emergency. This subsection contains information on different elements of emergency preparedness that are available on-site and off-site prior to an emergency.
4.2. Emergency response	Material which describes emergency response both on-site and off-site. Information on notification and communication of emergency to different stakeholders, as well as on protective actions aimed at the public and at emergency workers can be found here. It includes aspects with regards to the implementation of protective actions in a structured form, such as sheltering, evacuation, relocation and iodine thyroid prophylaxis.
4.3. Monitoring and assessment	Documents on the monitoring and evaluation of radiological conditions, as well as potential hazards on-site and off-site. The subsection is meant to assist in structuring material which describes radiological monitoring equipment and methodology for both on-site and off-site radiation survey.
4.4. Decontamination and recovery	Summary of decontamination measures on-site and restoration outside of the nuclear facility area. On-site decontamination involves information on other material in the facility and covers decontamination, description of experience with accident waste management, dust suppression and measures against secondary contamination. Off-site decontamination includes measures which are suitable for the overall area, settlement and buildings decontamination. Information on the transition to long term recovery is also addressed.

TABLE 5. TAXONOMY BRANCH 4: EMERGENCY PREPAREDNESS AND RESPONSE (cont.)

Subsection	Content
4.5. Medical response	Key terms on medical emergency preparedness and response to a nuclear emergency. It contains information on triage, immediate medical examination, ambulance transportation and treatment, as well as a description of radiation injuries that occurred during accidents.
4.6. Emergency and response analysis	Key terms on the review and analysis of an emergency, as well as reflection of the emergency response for a given emergency. It contains information on the modification of procedures, considering past experience, and includes information on action reconstructions, root cause analyses and corrective actions for future preparedness.

3.3.5. Scientific and technical support

The taxonomy branch 5 presents information on the scientific and technical support provided, typically by R&D or technical support organizations, to different stakeholders involved in the nuclear accident management and emergency response in tackling the consequences of an accident (see Table 6).

TABLE 6. TAXONOMY BRANCH 5: SCIENTIFIC AND TECHNICAL SUPPORT

Subsection	Content
5.1. Accident phenomena and progression	Information which describe methods and tools for zone diagnostics, neutron field measurements, reactor process modelling and neutron field measurement in a damaged zone and fuel condition diagnostics, among other things.
5.2. Methods for decontamination	Information on scientific and technical support employed for decontamination in general and radioactive dust suppression and water decontamination in particular in the course of past nuclear accidents, as well as new methods and techniques developed afterwards.
5.3. Waste management	Description of scientific and practical methods for handling solid, liquid and gaseous accident waste. Information on how and why certain methods are effective is summarized here.
5.4. Robotics for emergency	Description of robots and devices (modern and any state of the art at the moment of a given nuclear accident) applied for radiation monitoring, recovery works and decontamination.
5.5. Decommissioning	Terms and concepts which are critical to consider for an effective decommissioning programme. Experience gathered and documented on technologies to remove damaged fuel, radiological protection for decommissioning areas, as well as goals, strategy and dedicated training are structured and described here.
5.6. Long term programme development	Documented experience on long term living on contaminated areas and countermeasures for protection and recovery such as long term dose restrictions and hygiene standards.

3.3.6. Accident consequences

The taxonomy branch 6 focuses on direct and indirect consequences of a nuclear accident or event. It includes descriptions of both consequences and experience in their mitigation. It includes effects on human health and the environment, as well as social and economic impacts (see Table 7).

TABLE 7. TAXONOMY BRANCH 6: ACCIDENT CONSEQUENCES

Subsection	Content
6.1. Consequences for environment	Information on different types of release and fallout, which influence flora, fauna and aquatic environments.
6.2. Environment restoration	Description of measures for addressing consequences mentioned in 6.1 Consequences for environment. It addresses measures for recultivation of agricultural land and issues related to storage and treatment of declared nuclear waste.
6.3. Health consequences	Description of cumulative experience on deterministic, stochastic and psychological effects after nuclear accidents, as well as epidemiological assessments and methods for providing long term medical care for victims and workers who received a high dose.
6.4. Social and economic consequences	Summary of indirect consequences of a nuclear accident. These lie primarily in the area of disturbed agriculture, negative consequences on nuclear and other branches of national and global industry, issues on nuclear liability obligations and insurance. It also includes information on how an accident influenced the ethnocultural, political, legal and communication sides of the society where an accident happened.

Taxonomy terms should be viewed within the context of nuclear accidents and are meant to produce efficient search results and to act as metadata to associate taxonomy items with each other. In case a given search query retrieves certain content that is not relevant or contains an error, the taxonomy model should be reviewed and analysed for correct term association. A new term may need to be added to the taxonomy to retrieve the item appropriately. Terms used frequently or very seldom in indexing, and proven to be ineffective in retrieval, are candidates for deletion, modification or refinement by adding synonyms or related terms.

3.4. NUCLEAR ACCIDENT KNOWLEDGE TAXONOMY

This section contains the overall taxonomy developed in the nuclear accident knowledge domain and presented in Table 8. Certain terms are extended by synonyms and related terms (provided in parentheses) as examples to help and support IT specialists who will be configuring the taxonomy and query options within an environment capable of handling indexing and structuring of large information and knowledge repositories. The taxonomy has been developed up to different levels of depth for different subject areas. The depth of development is closely linked to the level of depth and the details users (subject matter experts) are usually interested in. However, the taxonomy can be customized for the specific needs of the implementing organization and can be developed in greater depth and in more detail, if required.

Text cont. on p. 28.

TABLE 8. NUCLEAR ACCIDENT KNOWLEDGE TAXONOMY

Subsections	Content	
	1. LEGAL AND GOVERNMENTAL FRAMEWORK	
1.1. Legislation and regulations	1.1.1. Laws (Acts, statutes, decrees, constitution, nuclear law, law on crisis management)	
	1.1.2. Conventions (International legal instruments)	1.1.2.1. Early notification
		1.1.2.2. Assistance
		1.1.2.3. Nuclear liability
		1.1.2.4. Nuclear safety
		1.1.2.5. Joint Convention on Waste and Spent Fuel
	1.1.3. Regulations and guides (Guidelines, requirements, guidance)	
1.2. Organization and authorities (Coordination)	1.2.1. Regulatory body (Regulator, regulatory authority, regulatory agency)	1.2.1.1. Regulatory framework
		1.2.1.2. Regulatory reports (Inspection reports, exercise evaluation reports)
	1.2.2. Operating organization (Operator, power plant, nuclear power plant, utility)	
	1.2.3. Response organization (Responders, liquidators, crisis management)	1.2.3.1. Civil defence
		1.2.3.2. Public health authorities (Health care organizations)
		1.2.3.3. Technical support organization
		1.2.3.4. Local municipality (Governance, judge, mayor, regional authority, local authority)
		1.2.3.5. Fire brigade (Firefighters)
		1.2.3.6. Police (Militia)
	1.2.4. Coordination and command (Interfaces in emergency, command and control system, coordination mechanisms, incident commander, decision maker, management system)	

TABLE 8. NUCLEAR ACCIDENT KNOWLEDGE TAXONOMY (cont.)

Subsections	Content	
2. NUCLEAR INSTALLATION STATUS		
2.1. Site conditions (Plant area, status, site parameters)	2.1.1. Natural conditions (Natural events, natural disasters, natural phenomena, climate conditions, external environment, external initiating event)	2.1.1.1. Earthquakes 2.1.1.1.1. Geotechnical conditions 2.1.1.1.2. Seismological conditions 2.1.1.2. Surface faulting 2.1.1.3. Meteorological events (Weather) 2.1.1.3.1. Tornadoes 2.1.1.3.2. Cyclones 2.1.1.3.3. Winds 2.1.1.3.4. Snowing (Precipitation) 2.1.1.3.5. Rain (Precipitation, fallout) 2.1.1.3.6. Atmospheric dispersion 2.1.1.3.7. Sandstorm 2.1.1.3.8. Forest and steppe fire 2.1.1.4. Water reservoirs and flooding 2.1.1.4.1. Seas and lakes 2.1.1.4.2. Rivers 2.1.1.4.3. High tide 2.1.1.4.4. Storm surge 2.1.1.4.5. Seiche 2.1.1.4.6. Wind waves 2.1.1.4.7. Tsunami 2.1.1.4.8. Surface water dispersion 2.1.1.4.9. Subsurface water 2.1.1.5. Geotechnical hazards (Danger, risk) 2.1.1.5.1. Slope instability 2.1.1.5.2. Mines 2.1.1.5.3. Water wells 2.1.1.5.4. Oil and gas wells 2.1.1.5.5. Soil liquefaction 2.1.1.5.6. Groundwater 2.1.1.6. Complex natural disasters (Combined natural disasters, multiple natural disasters)

TABLE 8. NUCLEAR ACCIDENT KNOWLEDGE TAXONOMY (cont.)

Subsections	Content	
	2.1.2. Human induced event (Conditions, disaster, catastrophe; human made, internal initiating event)	2.1.2.1. Aircraft crashes
		2.1.2.2. Explosions
		2.1.2.3. Pipelines (Gas pipelines, oil pipelines)
		2.1.2.4. Artificial reservoirs (Dams, weirs)
		2.1.2.5. Terrorism and sabotage
		2.1.2.6. Complex human induced events (Combined human induced events, disasters)
	2.1.3. Regional infrastructure (Local, area)	2.1.3.1. Demographic
		2.1.3.2. Industry
		2.1.3.3. Agriculture
		2.1.3.4. Substations and transmission lines (Electricity supply, grid, power supply, black out)
		2.1.3.5. Transport (Railways, roads, airports, water transport)
		2.1.3.6. Communication infrastructure (Communication tools, media, cell, mobile, radio, TV, cable and telegraph communication, high frequency communication, telecommunication provider, telephone)
2.2. Design (Specification, licensing bases, updated final safety analysis report, UFSAR, updated FSAR, stress test results, probabilistic safety assessment, PSA, probabilistic risk assessment, PRA, safety reassessment, FSAR, deterministic safety analysis, DSA)	2.2.1. Layout (Master plan)	
	2.2.2. Design basis	
	2.2.3. Reactor core (Cladding)	
	2.2.4. Reactor coolant systems (Primary coolant, core cooling, feed water line)	
	2.2.5. Containment system	
	2.2.6. Reactor shutdown system	
	2.2.7. Reactivity control	2.2.7.1. Control rod system
		2.2.7.2. Boron injection system
		2.2.7.3. Poison control (Burnable poison, liquid poison)
		2.2.7.4. Regulating systems (Liquid zone control, local power control, moderator level control)

TABLE 8. NUCLEAR ACCIDENT KNOWLEDGE TAXONOMY (cont.)

Subsections	Content	
	2.2.8. Instrumentation and control (I&C)	
	2.2.9. Power supply (Electrical power, electrical system, electrical power supply)	
	2.2.10. Communication systems (Internal communication system)	
	2.2.11. Balance of the plant	
	2.2.12. Auxiliary systems (Essential auxiliary systems, service auxiliary systems)	
	2.2.13. Steam and power conversion system	
	2.2.14. Heating, ventilation and air-conditioning systems (HVAC)	
	2.2.15. Radioactive waste management	
	2.2.16. Nuclear fuel management	
	2.2.17. Radiation protection and radiation monitoring	
	2.2.18. Fire protection	
	2.2.19. Water protection (Physical separation against flooding, waterproof)	
	2.2.20. Physical security	
	2.2.21. Safety structures, systems and components (SSCs)	
	2.2.22. Accident management SSCs	
	2.2.23. Essential support systems (Essential service systems)	
2.3. Operation	2.3.1. Utility (Operating organization, operator)	2.3.1.1. Organization structure, roles and responsibilities
		2.3.1.2. Staffing
		2.3.1.3. Personnel training
		2.3.1.4. Operational procedures
		2.3.1.5. Performance indicators
		2.3.1.6. Radioactive discharges
		2.3.1.7. Radiation protection
		2.3.1.8. Communication means (external)
		2.3.1.9. Configuration management

TABLE 8. NUCLEAR ACCIDENT KNOWLEDGE TAXONOMY (cont.)

Subsections	Content	
	2.3.2. Fuel management (Fuel assembly, fuel rods)	2.3.2.1. Fresh fuel
		2.3.2.2. Spent fuel
		2.3.2.3. Fuel material accountancy and safeguards (Fuel item accounting)
	2.3.3. Waste management (Radioactive waste, high level waste, low level waste, handling, treatment, collection, characterization, sorting, conditioning, pretreatment, storage, transport, disposal)	2.3.3.1. Liquid waste
		2.3.3.2. Solid waste
	2.3.4. Long term operation management	2.3.4.1. Modification (Modernization)
		2.3.4.2. Ageing management
		2.3.4.3. Periodic safety review (PSR)
3. ACCIDENT MANAGEMENT		
3.1. Accident management planning (Preparation)	3.1.1. Safety analysis results (*Link to 2.2. Design*) (Stress tests, probabilistic safety assessment, PSA, probabilistic risk assessment, PRA, fault tree analysis, event tree analysis)	3.1.1.1. External initiating events (*Link to 2.1.1. Natural conditions and 2.1.2. Human induced event*) (Natural, causes, reasons)
		3.1.1.2. Internal initiating events (Fire, leak, flooding, break)
	3.1.2. Accident management strategy	3.1.2.1. Roles and responsibilities
		3.1.2.2. Prevention of malfunction progression (Emergency operational procedures, EOP)
		3.1.2.3. Accident management guidelines (Severe accident management guidelines, SAMG, regulations, rules, requirements, instructions)
		3.1.2.4. Personnel training (Staff, employees, operational crew, skills, competences, drills)

TABLE 8. NUCLEAR ACCIDENT KNOWLEDGE TAXONOMY (cont.)

Subsections	Content	
3.2. Accident management implementation	3.2.1. Safety function maintenance (Recovery)	
	3.2.2. Confining of radioactivity (Containing, keeping, radiation)	
	3.2.3. Power supply maintenance (Recovery)	
	3.2.4. Ultimate heat sink maintenance (Recovery)	
	3.2.5. I&C for accident management (Instrumentation and control, accident monitoring, I&C integrity)	
	3.2.6. Long term safe condition (Stable, sustainable)	
	3.2.7. Communication for accident management (Coordination)	
	3.2.8. Fire protection	
	3.2.9. Water resistance	
4. EMERGENCY PREPAREDNESS AND RESPONSE		
4.1. Emergency preparedness	4.1.1. Hazard assessment (*Link to 2.1. Site condition and 2.2. Design*) (Emergency planning basis)	4.1.1.1. Methodology (Criteria, events considered, other conditions, pathways analysis, timeframes analysis, consequence analysis)
		4.1.1.2. Precautionary action zone (PAZ, reflex zone)
		4.1.1.3. Urgent protective action planning zone (UPZ)
		4.1.1.4. Broad planning (Extended planning distance, EPD, area for monitoring for relocation)
		4.1.1.5. Food restriction zone (Food restriction planning radius, ingestion and commodities planning distance, ICPD)
	4.1.2. Protection strategy (Justification, optimization, response strategy, response actions, protective actions, national strategy)	4.1.2.1. Generic criteria and reference level (Decision making criteria, dosimetric criteria, intervention level)
		4.1.2.2. Operational criteria (Generic action levels, operational intervention level, emergency action levels, triggers)
		4.1.2.3. Processes and actions

TABLE 8. NUCLEAR ACCIDENT KNOWLEDGE TAXONOMY (cont.)

Subsections	Content	
	4.1.3. Training and drills (Education, training, practice, training programme, national training, regional training, local training, facility training)	
	4.1.4. Exercise (Testing, verification, exercise programme, national exercises, regional exercise, local exercise, facility exercise)	
	4.1.5. Logistical support and facilities	4.1.5.1. Equipment and supplies (Commodities, stocks, communication systems, inventory)
		4.1.5.2. Infrastructure (facilities) on-site (Control room, auxiliary control room, supplementary control room, emergency centre, technical support centre, operational support centre, assembly points, escape route, shelters, public information centre)
		4.1.5.3. Infrastructure (facilities and locations) off-site (National, regional, local emergency centres, medical care facilities, hospital, transport means, shelters, assembly points, reception centres, emergency operating facility, public information centre, triage area, off-site notification point, national warning point, staging areas, entry points, exit points)
	4.1.6. Plans and procedures (Emergency response plan, emergency plan, facility plan, national plan, emergency procedures, instructions, coordination interfaces)	4.1.6.1. Facility plans and procedures
		4.1.6.2. Local and regional plans and procedures
		4.1.6.3. National plan and procedures (Emergency plans and procedures from response organizations)
		4.1.6.4. Bilateral and multilateral arrangements
4.2. Emergency response	4.2.1. Notifying (Identifying, informing, activating, information sharing)	4.2.1.1. Emergency classification (Emergency classes, general emergency, site emergency, facility emergency, alert)
		4.2.1.2. Notification points (On-site notification point, off-site notification point, national warning point, national competent authority, contact point)

TABLE 8. NUCLEAR ACCIDENT KNOWLEDGE TAXONOMY (cont.)

Subsections		Content
	4.2.2. Communication (Public and mass media, communication, informing, consultation of interested parties, communication with affected population)	4.2.2.1. With public and mass media (Alerting the public, warning the public, public communication)
		4.2.2.2. Among involved organizations and responders (Operational communication, coordination)
	4.2.3. Protective actions (Urgent protective actions, early protective actions, response actions, emergency action, intervention, intervention measure, mitigatory actions)	4.2.3.1. Evacuation of non-essential personnel on-site
		4.2.3.2. Evacuation of population
		4.2.3.3. Sheltering
		4.2.3.4. Iodine thyroid blocking (Iodine pills, iodine prophylaxis, iodine thyroid blocking, ITB, potassium iodide prophylaxis)
		4.2.3.5. Relocation
		4.2.3.6. Access restrictions
		4.2.3.7. Decontamination
		4.2.3.8. Food and commodities restrictions (*Link to 6.1.3. Impact on food*) (Long term countermeasures, long term protective measures, food, milk, drinking water restrictions, agriculture countermeasures, restrictions in agriculture and on non-food commodities)
		4.2.3.9. Land use restrictions (Industry, forest, recreation)
		4.2.3.10. Actions to prevent inadvertent ingestion
		4.2.3.11. Actions to protect trade and commercial interest

TABLE 8. NUCLEAR ACCIDENT KNOWLEDGE TAXONOMY (cont.)

Subsections		Content
	4.2.4. Emergency workers (Responders, contractors, workers, liquidators)	4.2.4.1. Designation and registration
		4.2.4.2. Provision of information (Informed consent, health risk information, instructions, doses received)
		4.2.4.3. Access regime (Contamination control, access restriction, security check-point, permitted contamination levels, sanitary check-point)
		4.2.4.4. Personal protection (Protective equipment, protective clothing, breathing protection, personal suits, respiratory protection)
		4.2.4.5. Monitoring equipment
		4.2.4.6. Medical care provision
		4.2.4.7. Iodine thyroid blocking (Iodine pills, iodine prophylaxis, iodine thyroid blocking, ITB, potassium iodide prophylaxis)
		4.2.4.8. Decontamination
		4.2.4.9. Protection of eyes
		4.2.4.10. Health surveillance
		4.2.4.11. Guidance levels (Restricting exposures, dose limits for emergency workers, criteria for emergency workers)
4.3. Monitoring and assessment (Radiation survey, radiation monitoring, measurement, dosimetry, release of radioactive material, radiological)	4.3.1. On-site monitoring (On-site dose assessment)	4.3.1.1. Radiation survey instruments (Measurement, monitoring, devices, equipment)
		4.3.1.2. Radiation survey methodology (Instructions, monitoring strategy)
		4.3.1.3. Occupational dose monitoring (Occupational exposure)
		4.3.1.4. Individual dose reconstruction
	4.3.2. Off-site monitoring (Off-site dose assessment)	4.3.2.1. Radiation survey instruments (Measuring, monitoring, devices, equipment)
		4.3.2.2. Radiation survey methodology (Instructions, monitoring strategy)
		4.3.2.3. Population dose monitoring
		4.3.2.4. Radiation survey of environment (Atmospheric transport, precipitation, fallouts, terrestrial and aquatic radioactive contamination, sampling, analysis)
		4.3.2.5. Radiation survey of foods, drinking water and other commodities
		4.3.2.6. Radiation survey of biota

TABLE 8. NUCLEAR ACCIDENT KNOWLEDGE TAXONOMY (cont.)

Subsections	Content	
4.4. Decontamination and recovery (Restoration)	4.4.1. On-site decontamination	4.4.1.1. Limitation of radioactivity spread (Sanitary barriers)
		4.4.1.2. Building decontamination (Building structure decontamination)
		4.4.1.3. Site decontamination
		4.4.1.4. HVAC decontamination
		4.4.1.5. Electrical, I&C decontamination
		4.4.1.6. Waste management
		4.4.1.7. Dust suppression
		4.4.1.8. Secondary contamination
	4.4.2. Off-site decontamination	4.4.2.1. Dust suppression
		4.4.2.2. Building decontamination
		4.4.2.3. Area decontamination (Forests, roads, fields)
		4.4.2.4. Settlement decontamination (Buildings, roofs)
		4.4.2.5. Waste management
	4.4.3. Transition to long term recovery	4.4.3.1. Transferring responsibilities, data and information
		4.4.3.2. Consequence assessment (Assessment of radiological situation)
		4.4.3.3. Conditions to be met (Goals for the transition, necessary conditions)
		4.4.3.4. Stakeholder involvement (Interested parties consultation)
		4.4.3.5. Adjusting protective actions (Revising restrictions, lifting protective actions)
4.5. Medical response	4.5.1. Medical radiological triage	
	4.5.2. Immediate medical examination	
	4.5.3. Ambulance transportation	
	4.5.4. Medical treatment (Signs of acute radiation syndrome, signs of ARS, radiation injuries)	
	4.5.5. Consultation (Medical counselling, psychological counselling)	
4.6. Emergency and response analysis (Evaluation, assessment, judgement, forecast, appraisal, review, accident, investigation)	4.6.1. Reconstruction	
	4.6.2. Root causes analysis	
	4.6.3. Safety implications	
	4.6.4. Corrective actions (Improvements, gaps)	

TABLE 8. NUCLEAR ACCIDENT KNOWLEDGE TAXONOMY (cont.)

Subsections	Content
	5. SCIENTIFIC AND TECHNICAL SUPPORT
5.1. Accident phenomena and progression	5.1.1. Zone diagnostics (Neutron field measurements, thermal methods of monitoring, visual methods of monitoring)
	5.1.2. Fuel condition diagnostics
	5.1.3. Reactor processes modelling (Thermodynamics radiation release modelling)
5.2. Methods for decontamination (Dust suppression, radioactive dust suppression, water decontamination)	
5.3. Waste management (Handling, treatment)	5.3.1. Solid waste
	5.3.2. Liquid waste
	5.3.3. Gaseous waste
5.4. Robotics for emergency (Robots, remote handling)	5.4.1. Robotics for radiation survey (Monitoring, measurement)
	5.4.2. Robotics for restoration (Robotics for recovery works)
	5.4.3. Robotics for decontamination
5.5. Decommissioning	5.5.1. Radiation and engineering survey
	5.5.2. Damaged fuel decommissioning programme (Fuel containing mass management programme, fuel pool damage, technology to remove fuel debris)
	5.5.3. Decommissioning goals (Criteria, objectives)
	5.5.4. Decommissioning planning (Design)
	5.5.5. Radiological protection for decommissioning
	5.5.6. Focused training programme
	5.5.7. Environmental protection and remediation
	5.5.8. Waste decommissioning programme
	5.5.9. Safety regulation
	5.5.10. Emergency response programme in decommissioning (EPR during decommissioning)
	5.5.11. Fuel material accountancy

TABLE 8. NUCLEAR ACCIDENT KNOWLEDGE TAXONOMY (cont.)

Subsections	Content	
5.6. Long term programme development	5.6.1. Prediction and prognosis	
	5.6.2. Territory zoning (Extended planning and ingestion commodities planning zones)	
	5.6.3. Dose restriction	
	5.6.4. Hygienic standards	
	5.6.5. Countermeasures (Protective measures, recovery measures)	
	5.6.6. Long term living on contaminated areas	
	6. ACCIDENT CONSEQUENCES	
6.1. Consequences for environment	6.1.1. Radioactivity releases to environment	6.1.1.1. Atmosphere (gaseous) releases
		6.1.1.2. Liquid discharge
		6.1.1.3. Radioactivity fallout/deposition
		6.1.1.4. Environment contamination (Soil, air, aquatic)
	6.1.2. Impact on environment	6.1.2.1. Impact on fauna
		6.1.2.2. Impact on flora
		6.1.2.3. Impact on aquatic environments
	6.1.3. Impact on food (*Link to 4.2.3.8. Food and commodities restrictions*) (Milk, fish, mushrooms)	
	6.1.4. R&D in environmental protection and restoration (Remediation, R&D for restoration)	6.1.4.1. Tools for accident consequences analysis (Techniques, experiments, tests, models, programs)
		6.1.4.2. Forecast of environmental condition (Environmental condition prediction)
6.2. Environment restoration (Remediation)	6.2.1. Decontamination (Remediation, rehabilitation, cleanup)	6.2.1.1. Separation (Soil washing, flotation, chemical/solvent extraction)
		6.2.1.2. Removal of the source (Subsequent separation procedures, disposal of balk material)
		6.2.1.3. Containment (Capping, subsurface barriers, containing radiation)
		6.2.1.4. Immobilization (Cement based solidification, chemical immobilization, in situ vitrification)

TABLE 8. NUCLEAR ACCIDENT KNOWLEDGE TAXONOMY (cont.)

Subsections	Content	
	6.2.2. Recultivation	6.2.2.1. Physical measures (Plowing, ploughing, earth covering, tree trunk washing, stripping topsoil, stripping weed, interchanging topsoil with subsoil removing litter layer, phytoremediation)
		6.2.2.2. Chemical measures (Soil amendment application)
	6.2.3. Waste management (Storage, treatment)	6.2.3.1. Solids
		6.2.3.2. Liquids
		6.2.3.3. Gases
6.3. Health consequences	6.3.1. Effects	6.3.1.1. Deterministic effects (Acute radiation syndrome, acute skin injury, fetus effects)
		6.3.1.2. Stochastic effects (Attributed effects, cancer, hereditary, thyroid diseases)
		6.3.1.3. Non-cancer diseases (Non-tumour, tumour, immunological effects, neuropsychiatric effects)
		6.3.1.4. Psychological effects (Fear, depression, stigma, distress, counselling)
		6.3.1.5. Effects of low dose radiation exposure
	6.3.2. Medical care (Medical examination, medical consultation, medical treatment)	
	6.3.3. Epidemiology assessment	6.3.3.1. Cohorts (Emergency workers, general public, age and sex groups)
		6.3.3.2. Methodology
6.4. Social and economic consequences	6.4.1. Impact on agriculture (Influence on, consequences for)	6.4.1.1. Restrictions on use of rural land and forests (Restriction for forest, restriction for land, land use)
		6.4.1.2. Restriction on shipment of agricultural products (Shipment restrictions, food shipment)
	6.4.2. Impact on industry (Consequences for industry, impact on energy system, electricity generation)	
	6.4.3. Economic losses (Direct losses, indirect losses, total losses, impact on trade, energy costs)	

TABLE 8. NUCLEAR ACCIDENT KNOWLEDGE TAXONOMY (cont.)

Subsections	Content
	6.4.4. Insurance
	6.4.5. Social effects (Effects, consequences)
	6.4.6. Political and legal effects
	6.4.7. Life of refugees
	6.4.8. Ethnocultural effects
	6.4.9. Public communication (Principles of public communication, messages, public perception, harmful rumours)

Note: Synonyms and related terms are provided in parentheses. HVAC — heating, ventilation and air-conditioning system; I&C — instrumentation and control.

4. SYSTEM APPLICATIONS

The approach used for the development of NAKOS is similar to that taken for the fast reactors knowledge organization system [7]. After the Fukushima Daiichi accident, it was recognized that there is a strong need for new systems that can support decision making and impact analysis through consolidating and retrieving information. Recently gained experience in addressing nuclear power plant accidents owes its origin in a great part to the three major accidents, which have strongly influenced the nuclear industry. The taxonomy presented in this publication has been developed using experience gained from these accidents, and is focused on events of this scale. The beginning of knowledge preservation in the system starts with the taxonomy development. The main details and issues are distilled and reconstituted in a hierarchical structure, then implemented in NAKOS. The taxonomy represents a frame which will be filled with information and documents on accident progression and consequence mitigation. The information will be automatically indexed, and later it can be retrieved by queries based on the taxonomy structure.

The hierarchy presented here reveals the step by step development of the taxonomy for severe accidents. There was a common thread in each accident — each time there was an attempt by personnel to keep the reactor in a controlled state. These efforts failed each time because of the lack of knowledge about plant conditions and because the severity of the overall situation was underestimated, including external circumstances. The consequences could have been prevented if experience from past accidents had been properly considered by regulatory authorities, as well as studied, analysed and communicated in advance to nuclear power plant personnel involved into operating and maintenance processes.

4.1. INTERNATIONAL APPLICATION OF NAKT: NAKOS

NAKOS, piloted by the IAEA, represents an international application of the knowledge taxonomy developed. The access to the system will be provided to organizations in IAEA Member States (see Section 2 for the technical requirements of NAKOS). In the long term, NAKOS should perform as both a structured archive of knowledge resources and a community of practice in which relevant experience and knowledge can be shared responsibly, and with controlled access if required.

For the pilot version of the system, knowledge resources originate primarily from the INIS database, the IAEA nuclear archive and international organizations. At further stages of implementation, resources from Member States' organizations will be included. More information on NAKOS can be found on the IAEA official web site.

4.2. NATIONAL APPLICATION OF NAKT: FUKUSHIMA DAIICHI NUCLEAR ACCIDENT ARCHIVE IN JAPAN

Besides using NAKOS, Member States can take the taxonomy as a standalone component. A domestic system with domestic content can be developed in a Member State. The Japan Atomic Energy Agency (JAEA), in cooperation with the National Diet Library, initiated the Fukushima Daiichi nuclear accident archive. For structuring information in the archive, NAKT was utilized.

Historically, the JAEA started to provide reference information about the Fukushima Daiichi accident in April 2011 via a special web site.[13] The content scope was later expanded with further information from the JAEA, such as R&D results, bibliographic references and reports of the investigation committee. In total, more than 20 000 items on the Fukushima nuclear accident have been provided.

Much of the information on the Fukushima Daiichi accident is not conventional literature, but rather published in different media, such as presentations shared during meetings which were later made available on-line. The JAEA started to construct the Fukushima Nuclear Accident Archive [17], which was launched on 23 June 2014, to incorporate such information into the system.[14] The structure of the archive is presented in Fig. 5.

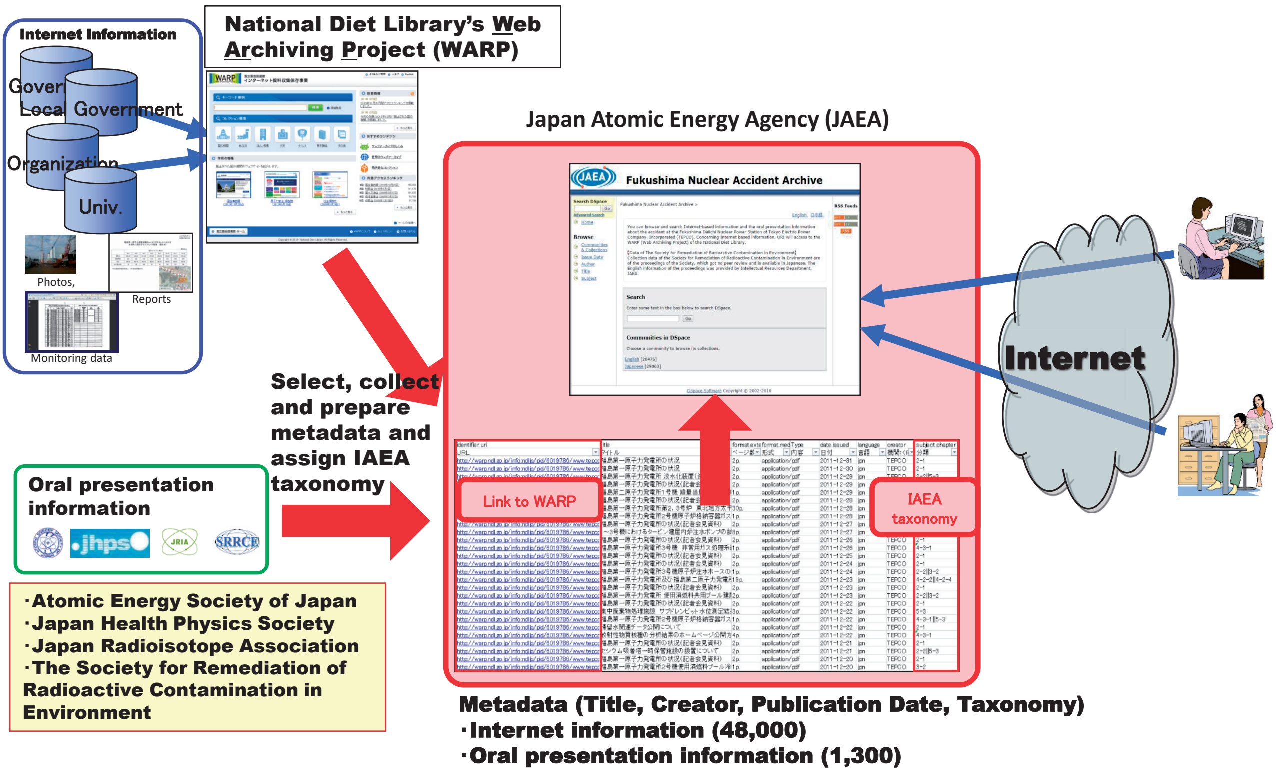

FIG. 5. Model of the JAEA Fukushima Nuclear Accident Knowledge Archive.

There are two information sources used for filling the system: on-line information and presentations. The JAEA collects and selects information, then prepares metadata and assigns classification in accordance to NAKT before placing information items into the archive system.

One of the important points is to assure permanent access to the information on-line. In order to do this, the archive is linked to the National Diet Library's Web Archiving Project (WARP). The JAEA Fukushima Nuclear Accident Knowledge Archive is a living project which complements NAKOS at the national level.

[13] See http://tenkai.jaea.go.jp/english/sanko/index.html

[14] See http://dspace.jaea.go.jp/dspace/index.php

5. CONCLUSIONS

There is a large amount of information and many technical resources on nuclear accidents which can be found on-line or in information repositories. Unlike specialized industry or organization specific databases used primarily for event reporting or consolidation of operational experience [17, 18], scientific, analytical, engineering documents and publications are often unstructured and difficult to analyse or use to learn from past experience. To address the challenge, it is essential to create an effective means to organize and assure access to information and explicit knowledge, accumulated from the past nuclear accidents. NAKOS is a tool for structuring, tagging, searching and retrieving appropriate information in the nuclear power plant accident knowledge domain. The developed taxonomy is an important part of the system, which can support users and stakeholders in finding and retrieving precise and relevant information on facts, consequences and mitigation methodology for nuclear accidents. It can be concluded that NAKOS should have the following features:

(a) The nuclear accident taxonomy should be sufficiently comprehensive and versatile to be a helpful search and classification tool.
(b) The taxonomy should be expandable to meet the needs of potential users and the specific relevant user groups for the system.
(c) The taxonomy should serve as a structured collection of terms which is consistent with the IAEA Safety Glossary [9] and considers other terms used in literature and reports.

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ABBREVIATIONS

HVAC	heating, ventilation and air-conditioning system
I&C	instrumentation and control
INIS	International Nuclear Information System
JAEA	Japan Atomic Energy Agency
NAKOS	Nuclear Accident Knowledge Organization System
NAKT	Nuclear Accident Knowledge Taxonomy

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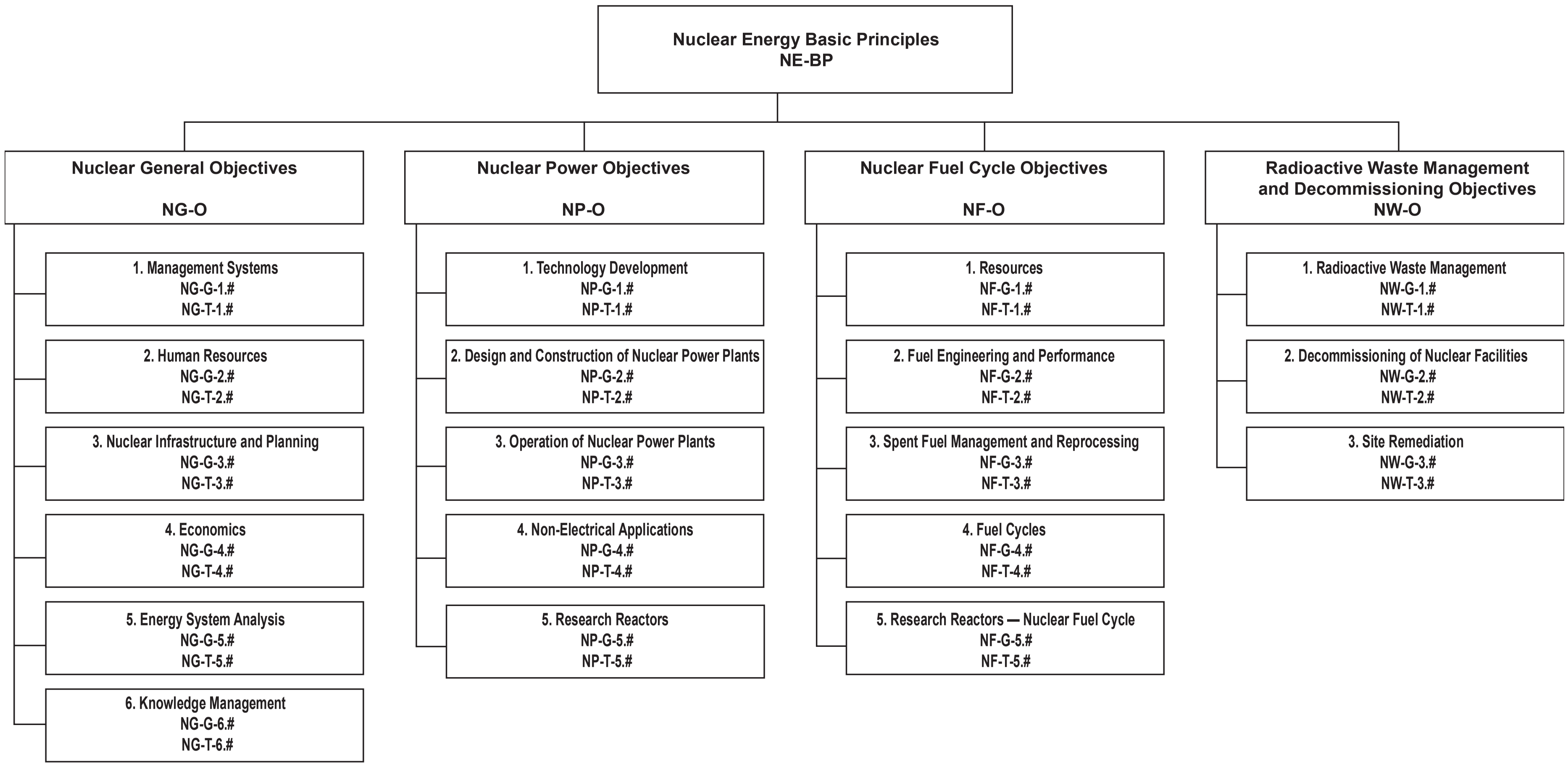

Key

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