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Long Term Preservation of Information for Decommissioning Projects

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LONG TERM PRESERVATION OF INFORMATION FOR DECOMMISSIONING PROJECTS

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FOREWORD

The objective of final decommissioning should be considered from the earliest stage of the life cycle of a facility, and needs to focus on the acquisition and maintenance of the relevant records. In performing the detailed planning for the permanent shutdown of a facility, a dedicated effort is needed to develop the strategy for the selection and management of the key records. As published information and guidance on record keeping relevant to nuclear decommissioning is relatively scarce, more attention needs to be placed on the management and organization of records. Experience indicates that a lack of attention to record keeping may result in a costly misallocation of resources and may present problems of safety. The objective of Technical Reports Series No. 411 (2002) (TRS 411) was to provide information, to relate experience and to give assistance on how to identify, update as needed and warrant access to the records necessary to assist in the decommissioning of nuclear facilities.

As a significant aspect of record keeping, it is important to make provisions to retain the most important information to facilitate future decommissioning, even in long term projects. When there are significant delays between permanent shutdown and the completion of dismantling, arrangements must be put into place to ensure that the necessary information is preserved. This refers not only to the physical preservation of information, but also to its legibility and the skills needed to understand its technical meaning and to start in due course. As a follow-up to TRS 411, this report is intended to present information and provide practical guidance on long term preservation of information and technical knowledge in decommissioning projects. A preliminary draft was prepared by an IAEA consultant, F. Takats, Hungary, and the IAEA technical officer, M. Laraia, responsible for this publication. Following the preliminary drafting, a series of consultants meetings was held to review and amend this report, at which a number of international experts participated. Special thanks are due to D. Lemire, Canada, who chaired the meetings and coordinated the preparation of the final report.

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SUMMARY

This report aims to provide guidance to Member States who are planning to carry out long term decommissioning projects on the approaches and technologies that can be used for the organization, maintenance, and later use of records that span a wide range of time and operating environments. The report was prepared as a follow-up to Technical Reports Series No. 411 [1], which dealt with the management and organization of records for decommissioning. It draws on the growing body of experience, both positive and negative, related to the preservation of documentation and the retention of the essential skills required to successfully plan and carry out decommissioning activities. In capturing and organizing 'lessons learned', the report provides a timely reminder to decision makers and practitioners alike that a lack of attention to record keeping may result in a costly misallocation of resources and may also present problems of safety.

The objective of final decommissioning should be considered from the earliest stage of the life cycle of a facility. In particular, detailed planning for the permanent shutdown of a facility requires a strategy for the selection, acquisition and maintenance of relevant records. Published information and guidance on record keeping relevant to nuclear decommissioning is relatively scarce: this report focuses on means to address this gap.

When there are significant delays between permanent shutdown and the completion of dismantling, arrangements must be put into place to ensure that the necessary information is preserved. This refers not only to the physical preservation of information, but also to its legibility, the skills needed to understand its technical meaning and a commitment to act in time. Thus the process should emphasize both the *physical* and the *human* aspects associated with the transfer of knowledge. For the physical aspects, the strategies elaborated in the report include the means to ensure records preservation over time, such as adequate planning and budgeting, use of proven electronic records management tools, provision of safe secure storage facilities, and duplication of stored copies of records. To address the human aspects, future strategies need to ensure that the knowledge records, skills, techniques, languages, tools and experience needed by future generations to use the core information are available. In particular, means to appropriately recruit and train the necessary knowledge workers need to be addressed.

The characteristics of appropriate records management systems (RMSs) are considered in this report. The features and benefits of alternative records strategies, including both all-electronic approaches and document management applications (DMAs) that work with mixed formats, are discussed, and the

desired characteristics of a preferred system combining attributes of both are outlined.

A number of examples of failures in records keeping are discussed in the 'lessons learned' section (Annex II) and factored into the development of preferred solutions. These include insufficient/inadequate records backup, failed electronic media (magnetic media and CDs), software and hardware obsolescence in records storage or retrieval, improperly executed records destruction initiatives and inadequate labelling of stored nuclear waste materials.

It is anticipated that this report will be used by policy makers, regulators, owners, operators, decommissioning contractors and other interested parties who are involved in or who need to prepare for the process of decommissioning. Information presented should also be useful to those addressing the various scientific, technical and non-technical issues that affect decisions relating to the long term preservation of information.

1. INTRODUCTION

The records from the beginning of the operation of a nuclear facility are essential for its safe and efficient operation. This set of records needs to be constantly updated and augmented during the facility's operation and should include, for example, any modifications, its operational history and details of any incidents that lead to unplanned contaminations of the systems, structures, components and land. The objective of final decommissioning should be considered from the earliest stage of the life cycle of a facility and needs to focus on the acquisition and maintenance of the relevant records. In performing the detailed planning for permanent shutdown of a facility, a dedicated effort is needed to develop the strategy for the selection, transfer and management of the essential records. An IAEA technical report addresses record keeping for decommissioning and stresses the need to establish a decommissioning-oriented records management system (RMS) as early as the design and construction phase [1].

An RMS is essential for the collection, cataloguing, maintenance and dissemination of records for the required time frame, which could be many decades. The RMS needs to be established with written instructions, procedures or plans with quality assurance (QA) procedures, and regular independent auditing is necessary at all stages. The primary focus of a decommissioning RMS is to ensure that the relevant records are selected to support decommissioning and that the record's sources are validated, as appropriate. This may include the preservation of the necessary information for the duration of the active institutional control period and, where necessary, beyond this period.

Most large decommissioning projects will last more than one decade, although the implementation of the decommissioning strategy may have been initiated soon after final shutdown (immediate dismantling). From a records management perspective, this would be considered as long term.

It is clear that record keeping for a deferred dismantling strategy or any delayed decommissioning projects involves long term records storage and that retrievability concerns are significantly greater than those for immediate dismantling. For long term decommissioning, which may take place decades after the closure of a facility, the opportunity to debrief personnel will probably no longer exist when the decommissioning actually begins. Full reliance will, therefore, have to be given to the records assembled during the design, construction, operation and shutdown of the facility, and to earlier personnel debriefings. These records will have been stored for future use over a period of several decades. It is evident that issues such as legibility, preservation and retrievability over such long time spans are important for this strategy.

In recent years, a growing awareness of long term ecological problems has lead to a move away from treating environmental problems only after they have occurred. The goal is to avoid environmental impacts from the very beginning in the life cycle of a human activity. This life cycle management aims to treat each stage in the life of a facility or site not as an isolated event, but as one phase in its overall life. Thus, the planning does not only cover each stage but is also a continuing activity, taking into account actual and projected developments [2].

As a consequence, a more proactive integrated management of human activities also became part of the legislation in many Member States. In many countries there are also regulatory constraints, which require companies to retain records and be able to produce documents for any legal review. Therefore, it is important to consider the longevity of the records generated, as well as the ability of future generations to read and utilize them. Although an explicit requirement to make available reliable and relevant information to future generations is not directly addressed in current IAEA publications, Article 11 (vii) of the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management [3] requests the avoidance of "undue burdens on future generations". The concepts of "burdens on future generations" and "protection of future generations" are also highlighted in an IAEA Safety Series publication [4]. More generally, "the IAEA has an obligation to lead activities towards preservation and enhancement of nuclear knowledge by complementing, and as appropriate supplementing, activities by governments, industry, academia and international organizations" [5]. A statement made by the Organization for Economic Co-operation and Development (OECD) Nuclear Energy Agency in one of its reports [6] illustrates the same concept:

> "The generations using nuclear power facilities have an obligation to assemble and to preserve the financial, technical and scientific resources necessary for the later decommissioning of these facilities."

1.1. OBJECTIVES

The objective of this report is to provide Member States planning to carry out long term decommissioning projects with guidance on the approaches and technologies that can be used for the organization, maintenance and later use of records that span a wide range of time and operating environments.

There is a good deal of experience and information available on the methods, approaches and technologies that provide for efficient organization, maintenance, use and disposition of records. This report draws on such a body of experience and information.

Since there is already a wealth of published information and guidance on the suggested type of decommissioning records and on general aspects of record keeping for nuclear facilities, the report rather focuses on ensuring the long term availability of records and retention of information about records and the maintenance of the skills necessary to maintain the records for the decommissioning period.

It is anticipated that this report will be used by policy makers, regulators, owners, operators, decommissioning contractors and other interested parties who are involved in or who need to prepare for the process of decommissioning. The information presented in this report may also be useful to a wider audience when addressing the various scientific, technical and non-technical issues that affect decisions relating to the long term preservation of information.

1.2. SCOPE

The scope of this publication is to report experience in the preservation of records for long term or deferred decommissioning of all types of nuclear installations, from experimental and research reactors through to large commercial facilities, including fuel reprocessing and storage facilities. Recognizing that the decommissioning strategy selected may dictate the record keeping requirements, particular attention is given to the decommissioning of large nuclear facilities such as nuclear power plants (NPPs) because, for those facilities, implementation of active decommissioning is often deferred for several decades (safe enclosure[1]). In all cases, the process requires the establishment of a long term record keeping process to transfer knowledge of the state of the facility to the dismantling team. Special attention should be given to smaller facilities such as research reactors and medical, industrial and other research facilities, owing to factors such as the low priority given to decommissioning by research teams and the possibility of poorly recorded structural and operational changes. The widespread distribution of research reactors, including a large number of countries with limited resources, underlines the value of guidance and experience of long term information preservation in long

[1] Called ‘care and maintenance’ or ‘stewardship’ in other parts of this report.

term decommissioning projects. It is important to ensure that the information retained in the RMS will be legible and useable by future generations and that the logic behind the selection of the information for retention will also be legible and useable.

This report discusses:

(a) The provisions related to records that are needed to ensure the safe decommissioning of nuclear facilities when there are long delays between shutdown and the implementation of final decommissioning activities;
(b) Practical guidance on means for ensuring that information relevant to decommissioning, including records and general information about the context in which the records were created, remains available and legible in the long term, and that there are individuals and companies capable of utilizing them;
(c) Reported experiences, both positive and negative, and lessons learned in the management of data for decommissioning purposes.

A generic approach is provided in IAEA Technical Report No. 411 [1] to the early and timely creation of an RMS that is decommissioning oriented in view of eventual decommissioning. Once the RMS is in place, the problem remains how to extend its applicability over a long period of continuous dismantling[2] or safe enclosure, if deferred decommissioning is the selected strategy. The scope of this report is thus limited to the necessary process steps in preserving these records while maintaining their usability. In other words, Ref. [1] is the baseline for this report, and considerations aimed at the safe and cost effective creation of an RMS will not be repeated here, except to the extent that this information is useful in assessing long term aspects. The 'flagging' approach mentioned in Ref. [1] (i.e. the early identification during design, construction and operation of records relevant to decommissioning) is one important example. In addition, note that Ref. [1] was intended primarily for facility operators, to ensure that they were managing records properly for future decommissioning requirements. This report has a broader clientele that also includes regulators, contractors, site planners and other parties.

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[2] In the US literature, a prolonged period of active decommissioning is often termed 'incremental decommissioning'. It currently applies to plants such as Big Rock Point or Rancho Seco.

In summary, four major technical areas will be addressed:

(1) Records preservation over time;
(2) Periodic assessment of records, and criteria for the assessment for long term preservation;
(3) Records transfer and sharing;
(4) Long term training and competence building.

Two IAEA TECDOCs, a Technical Report and a Safety Report describe records management at radioactive waste management and disposal facilities [7–10], and therefore these areas are not covered in this report, although some principles quoted in those publications remain valid even in the domain of decommissioning. It is also recognized that certain observations made in the older references may reflect out of date views, as considerable developments have been made since then in the archiving community.

Excluding records management, other planning, management and organizational aspects of decommissioning are discussed in IAEA publications [11, 12] and are also covered by relevant documents of the Member States; therefore, they are not specifically addressed in this report except to the extent that they corroborate records related matters.

2. INFORMATION TRANSFER FOR DECOMMISSIONING

This section provides general guidance about the selection of the required amount and level of information for decommissioning projects. Although long term activities at a site will be driven by site specific factors and needs, the practices described in this report provide general guidance. Detailed information on collecting these data is provided in Ref. [1], and specific examples or episodes are also described in some detail in the two annexes of this report. Reference [1] provides a generic approach to the early and timely creation of an RMS.

When reviewing historic documents, the decommissioning organization should have a good understanding of the type of information that will be required. It is absolutely essential that the decommissioning project decision makers have a good understanding of the facility and its condition before the facility is shut down and while facility staff are available to transfer their knowledge of the facility.

Records must be managed to ensure that the information that they contain is available when needed. Without effective records management, the records needed to conduct a long term decommissioning project will be at risk of loss, deterioration or destruction.

It is assumed for the purpose of this report that all records mentioned in Ref. [1] are available and that the RMS has the most important features mentioned in Ref. [1], such as the identification of records of particular importance for decommissioning (the ‘flagging’ approach mentioned in Ref. [1]). This ideal situation may not exist in some cases; however, the periodic assessment of records may also be a valuable tool for improvement in this respect.

Records are typically defined to include all books, papers, maps, photographs, machine readable materials, videos or other documentary materials, regardless of physical form or characteristics.

A large number of documents and records are necessary to properly support a delayed decommissioning project. A limited number of these records may be electronically scanned and/or indexed, and thus relatively easy to locate and retrieve. Many other records will exist only in hard copy and may be poorly catalogued, if at all. A thorough assessment of records should be conducted and a records transfer plan should be prepared prior to turnover.

It should be noted that a good RMS could be more easily transferred to and utilized by future dismantlers than a poor one. An incomplete or inadequate RMS at the time of its creation (e.g. around final shutdown of a given facility) has hardly any chance of being improved at a later stage. One only has to consider the radiological characterization of difficult-to-reach areas: over time even the notion of these areas might disappear. In general, the elements that contributed to the initial difficulties will make matters worse over time (e.g. because of structural deterioration in the aforementioned case). In the case of a poor RMS being in place at the start of decommissioning, those in charge should resist the temptation of taking advantage of a long period of safe enclosure to pass on the ‘burden’ to future dismantlers. It is the responsibility of regulators to pressure operators to improve the status of records as soon as possible.

The documents included in the RMS may be subject to varying statutory periods, and some may have long term historical value (national archive requirements). Additional statutory requirements, internal and external accountability and relevance to historical/scientific importance need to be considered when assigning retention periods. As a general rule, inactive temporary records that are no longer needed to perform decommissioning should be reviewed and disposed of.

In the case of a nuclear facility to be decommissioned, records must be retained until they are permanently removed from service, and all dismantling, removal and restoration activities are completed. Records retention should be evaluated by the same criteria for all information regardless of the medium on which it is created and stored. Substantive changes to existing records constitute the creation of new records, while minor changes may not.

Records about a nuclear facility containing data, information and knowledge are diverse in nature (paper documents, spreadsheets, emails, Internet content, engineering drawings, schematic diagrams and databases), complex and voluminous. In planning for the actual decommissioning of a nuclear facility, it is necessary to have as much knowledge as possible about the radiological conditions and hazards, as this will serve to facilitate decommissioning by minimizing occupational exposure and reducing the risk of any public exposure.

The information necessary to carrying out decommissioning activities and to ensuring protection of workers and the environment against radiation hazards during decommissioning resides in a vast array of documents, computer databases and records. In some cases, the necessary information may not be formally documented at all. Rather, it resides with individual employees of the nuclear facility or with the nuclear component supplier organizations and the facility owner.

If a facility to be decommissioned is operated or decommissioned by different contractors, it is important to establish a comprehensive records management programme for all workers and contractors. The term ‘contractor records’ is frequently applied to paper, audiovisual material, and electronic records and data created, received from or maintained by contractors for the owner of the site. Contractors may create records essential for effective management, and for accurate and complete documentation of these functions. Unless contract provisions explicitly define the documentation to be provided to the site owner, contractors are likely to treat needed documentation as private property. To avoid this, the decommissioning organization should ensure that contractors are required to provide this information for inclusion in the decommissioning RMS. The contractor performance should be continuously monitored and evaluated, to ensure that the proper records management practices are followed. It is essential to stress that, while individual tasks (in this case records management) can be delegated by the licensee to contractors, the overall responsibility cannot be transferred.

In general, contractors may be more vulnerable to incidents such as bankruptcy, uncontrolled organizational changes or other unexpected events ultimately leading to the loss of records. The responsible entity will have to assume full control of the records and many may choose to maintain separate copies of the records. It is, however, possible that even the operating organization may go bankrupt and the State may have to take over incomplete decommissioning projects. It is understood in the Joint Convention [3] that the State will ultimately have a responsibility for safe waste management. This concern would be reflected in different ways in different legal structures, but it follows that decommissioning, and, in particular, deferred decommissioning, warrant concern from Member States. To reduce this risk, some countries may require that records be stored at national archives and controlled by government. Copies of records can be kept on-site at the shut down facility. For the purposes of this report, provisions apply to all entities responsible at any time for record keeping.

The type and reliability of available information tend to be site and case specific. If the facility is in the operational phase, the operational records and available modification data become important, together with information such as the levels and locations of radiation and the quantities of specific radionuclides present in the areas of the facility that are to be decommissioned.

The most important areas to address are:

- Information content and media;
- Records management tools;
- Procedures for records keeping;
- Physical management of records;
- Efficiency and cost effectiveness;
- Knowledge management.

2.1. INFORMATION CONTENT AND MEDIA

Several types of persons and entities may require decommissioning information in the future. Primary users are those entities that are responsible for performing or overseeing decommissioning functions at the site and for providing administrative support for those activities. Users external to the site include emergency response personnel and community planners. An initial identification of potential users should be made, together with a determination of their associated activities and data needs.

It is critical that timely attention be given to the management of facility operational records relevant to decommissioning and records for statutory, legal, technical or commercial purposes. These would include: ownership title deeds, operating licence documentation, technical records to support continued operation, maintenance records, safety cases, staff health and dosimeter records, and financial accounts. A focus on future decommissioning, as a factor determining selection and preservation of records, should be given high priority in nuclear facilities.

With regard to decommissioning, each licensee is required to keep records important to the safe and effective decommissioning of the facility at an identified location(s) until some period of time after the licence has been terminated by the regulatory authority and 'greenfield' conditions have been achieved. In addition, the records may also be needed longer for historical, future decommissioning or liability reasons. As a result, systematic data management and record keeping are an essential part of decommissioning, owing to the long period involved.

Records important for decommissioning (e.g. for site decontamination, dismantling, and care and maintenance) are required to be identified and need to be retained in the context of decommissioning plans. The practice of retaining everything in the hope that it will be suitable for decommissioning might result in an inordinate quantity of documentation, which is often unmanageable and may result in the loss of valuable information. Guidance on the management, criteria and experience in record keeping for decommissioning purposes has been addressed in Ref. [1].

As a general principle, records to be retained are required to address obligations imposed by legislation, and should thus:

(a) Comply with statutory and regulatory requirements;
(b) Provide support for future decommissioning activities, that is:
  — Assist in the safe dismantling of the facility;
  — Enable safe storage of nuclear material;
  — Enable safe identification, recovery and disposal of radioactive material;
  — Assist in minimizing doses during decommissioning;
  — Assist in decommissioning planning.

Having established the fundamental nature and the necessary amount and level of information, there is often a requirement for additional documentation, because the existing information is deficient and further documentation is necessary. These cases could be caused by:

(a) Changes to the plant conditions;
(b) Lack of clarity about regulatory changes or requirements;
(c) Lack of understanding about historic technical matters;
(d) Insufficient knowledge of the plant characteristics and conditions.

Information should also include records of spills or other unusual occurrences that took place over the operating life of the nuclear installation where significant contamination may remain. Only records on contamination that could have a significant impact on decommissioning methods, costs or occupational exposures should be included in the record file. The need for intrusive characterization activities (sampling and analysis) necessary to adequately understand hazards should be determined. Additional intrusive characterization should be considered if the knowledge of hazards is insufficient to support an understanding of hazardous material types, quantities, forms, potential exposures, locations and methods for hazard reduction or removal, as well as whether such information is needed to support decommissioning activities. Facility drawings should include all structures, systems and components (SSCs). In addition, it is necessary to maintain the knowledge required to interpret and understand the records and information.

The application of revised specific record keeping requirements may necessitate reassessing the processes and techniques established during the operation of the facility, or upgrading the RMS to comply with the new requirements. These actions should take place as early as possible, to prevent the loss of operating experience that will assist in the decommissioning process. In any case, facility operating procedures should clearly define responsibilities for collection, retention, maintenance, updating and retrieval of the decommissioning records. These records should be reviewed periodically by plant management, to ensure their completeness and ability to serve their intended function. Facility changes should be reflected as they occur.

Media involved are paper, film and other photographic records, microforms, digital records and silicon carbide tiles. Detailed information on these media is given in Section 3.2.

2.2. RECORDS MANAGEMENT TOOLS

Records management systems — or document management systems in some countries — enable an organization to create, index, search, save and locate documents containing design information stored electronically. An RMS should be established and implemented by the responsible organization as the records are developed or obtained and released for use. The records management organization should already exist as a licensing requirement for the facility and should be transferred to the decommissioning organization. If there is a change of ownership of the facility, appropriate procedures must ensure that access to records be maintained and preferably transferred to the new owner.

It is strongly recommended that an operational RMS be transferred to the decommissioning organization and that it becomes the RMS for decommissioning; as such, it would continue to be used, enhanced and maintained. This will allow the RMS to continue to be useful and up to date throughout decommissioning.

An RMS may incorporate electronic records management applications (RMAs), of which there are two distinct types. By properly incorporating these RMAs into an RMS the ability to access, manage, control, retrieve, disseminate and dispose of records will be enhanced.

The first type is the RMA or electronic records management system (ERMS), which is an electronic system whereby records are collected, organized and categorized to facilitate their preservation, retrieval, use and disposition. Records management systems have several beneficial features:

(a) They can track and manage documents in their 'native system' as they are created and passed from one point to another as work in progress. When the agency determines that the document is ready to be declared a record, it is frozen as such and filed in the computer under a hierarchical file classification scheme. Future searches of records are made by electronic queries.
(b) Records are managed by having retention schedules programmed within the RMA, which then organizes the disposable files and generates destruction approval notifications.
(c) They address the entire life cycle of records from creation, maintenance, and use to disposition.
(d) They work well with mixed electronic record formats, and also manage paper and other hard copy media.

However, RMAs have potential drawbacks:

(a) Retention schedules must be entered and maintained with the RMA, which for the most part is still a very manual process.
(b) They do not handle documents in progress very well, because they assume that each document version is a record.

The second type is the DMA or electronic document management system (EDMS), which is a set of software and hardware applications that provides for the management of documents and has the following capabilities:

(a) Supports the processes of creating, editing and reviewing work in progress.
(b) Manages the creation, storage and control of documents during daily use.
(c) Works well with mixed electronic record formats and can provide revision and rendition controls.

(d) Provides for sharing files and information — multiple project participants can work simultaneously in decentralized locations from a single master file, enabling everyone involved to be familiar with the same information at all times.
(e) Provides immediate functionality to management of documents during daily use.

Traditionally, EDMS solutions have had certain limitations such as:

(a) They do not effectively handle inactive information needed for historical or legal purposes.
(b) They do not support the preservation of the business context of an individual record (i.e. content items are managed as individual units, instead of preserving their relationships to a larger group of documents that provide evidence of the same particular organizational function).
(c) They are not equipped with retention management components that track retention requirements, disposition and/or destruction options (indexing is still required to find information that has been managed and stored).
(d) They usually do not address hard copy or other non-electronic media.

Most RMA systems and EDMSs are now integrated, such that the capabilities of both are shared.

Records management is defined as the policies, procedures, guidance, tools and techniques, resources and training needed to design and maintain reliable and trustworthy records systems. Records must be managed throughout their life cycle: from creation, through maintenance and use, to final disposition (which does not necessarily mean destruction).

The records system should ensure that records are specified, prepared, authenticated and maintained, as required by applicable codes, standards and specifications.

The decommissioning RMS should ensure that records are:

— Categorized;
— Registered upon receipt;
— Readily retrievable;
— Indexed and placed in their proper location within the record facility files, with the retention time clearly identified;
— Stored in a controlled environment;
— Corrected or supplemented to reflect the actual plant status;
— Supporting the later decommissioning work;

— Identified in their location (backup and originals);
— Integrated, for example, in the management of non-electronic and electronic documents;
— Taking into account the distributed management of documents ('local' management versus 'corporate' or central management).

It is important to develop an information collection programme and to ensure that adequate resources are available to support storage and retrieval of records and personnel training. A detailed list of the documents to be included in the RMS should be established and maintained at the earliest practicable time, and systematic collection of design and relevant operation data should have already been initiated during the design and construction phases.

The term 'indexing' in this report refers to the process of referencing the content of records through metadata including keywords, subject codes and other identifiers, to facilitate searching and retrieval. Without a standard method of indexing, it may be difficult or impossible for future generations to identify and access decommissioning records. Efforts are under way in some Member States to develop standard metadata, filing structures and naming conventions for electronic data, and hard copy records.

Having identified and located the required information, various approaches can be used to compile the information in an RMS, such as:

(a) Records organized by facility system, structure or on a topical basis. This can be accomplished manually if the records are retained in hard copy or, if retained in microform or electronic media, as a listing of the records and their locations.
(b) Establishment of a master cross-reference index. This method does not involve assembly of hard copy records; rather it requires development of an information system with capabilities to facilitate retrieval.
(c) Development of unique decommissioning records. This method is generally the most resource intensive approach, involving the development of a unique set of decommissioning records. These are stand-alone documents, which contain the information necessary to document the as-built condition of the facility systems, structures or components, and could be used as a reference during the detailed design of decommissioning steps. Decommissioning records may take whatever format is suitable for the facility. To this end, the 'flagging' approach described in Ref. [1] is invaluable.

The systems that were developed during the engineering, construction and early operation phases of the facility's life cycle may not prove adequate to support current information needs. The information systems developed and maintained by the construction and operating organizations may fall into disuse or be entirely eliminated with the transition to decommissioning. If still in use, the records systems should be examined for their compatibility with other decommissioning information systems and for their capability to be consolidated with them.

Establishment of an RMS and information system enhancements required to support decommissioning needs should be implemented in accordance with decommissioning policies and resource availability. The responsibilities for maintaining and operating the records system should be clearly defined and documented.

The feasibility and implementation of electronic records management technologies in a given country are key aspects in the selection of a good RMS strategy. The RMS strategy must be capable of being implemented using existing, and preferably mature, technologies. If these do not exist, some development will be required. Care must be taken to ensure that the use of one particular electronic records management technology does not compromise the already gathered information.

During operation of the facility, a large amount of information will be generated and available to support decommissioning needs, if such records are properly managed. The RMS needs to develop a standard methodology for identifying the portion of this information that will be critical to support decommissioning activities.

There are a number of different types of RMSs, which can be applied to decommissioning projects. A range of project specific provisions are quoted in Ref. [1] as well as in the national annexes attached to this report. See also Refs [15, 30, 31].

Typical management tools for records management in the Member States are:

(a) United States Department of Energy (USDOE), System of Tracking Remediation, Exposure, Activities and Materials (STREAM) [13];
(b) European Commission, EC DB TOOL and COST [14];
(c) Germany, Greifswald, Project Information System [15];
(d) IAEA, Net-enabled Waste Management Database (NEWMDB) [16].

Figure 1 shows a schematic illustration of an example of an integrated RMS [1].

Whatever the arrangements, dedicated workrooms, computer servers and other tools are necessary to ensure that both hard copy and electronic

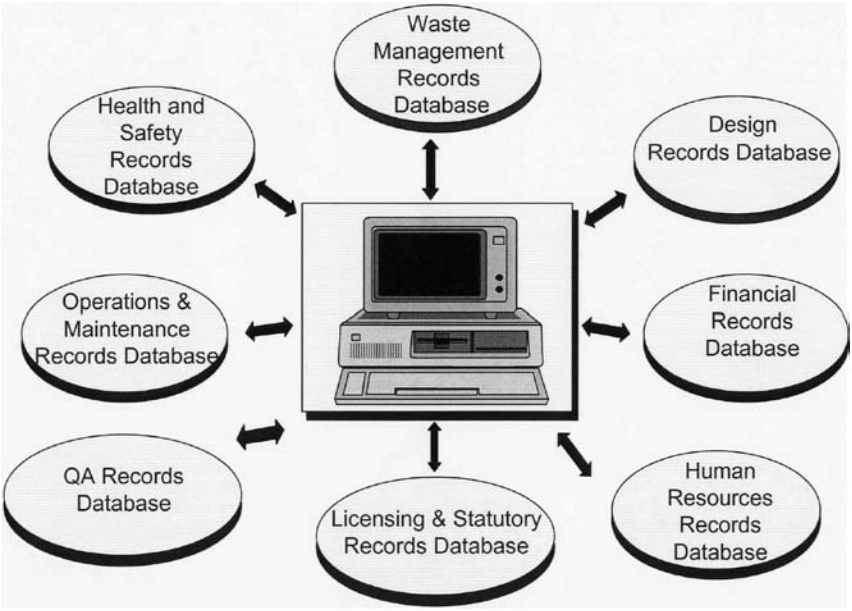

FIG. 1. Schematic illustration of a computer based integrated management information system.

documents are kept separate and secure. Redundancy, separation, control and security issues are covered in Section 3.

Records should be retained for no less than their authorized retention period as established by an existing records retention and disposition schedule. Records should be reviewed periodically, to assess their ongoing business value prior to final disposition or destruction. Retention periods must be reviewed and updated regularly. Complete, accurate and current documentation of both the system and the data should be maintained until use of the information system is discontinued and the longest retention time applicable to records stored in the system has expired. Records retention schedules should include new records that are created as a result of decommissioning.

Additional information needed to establish electronic records retention requirements and retention periods for records produced, contained in or maintained by the RMS should be regulated by the countries involved. Some considerations are listed below:

(a) How long is information needed on-line and can on-line retention requirements be met by the computer operating system or application software?
(b) Should information be retained near-line or off-line, in what storage media, and for how long after the originating department no longer needs the on-line data?
(c) Identification of off-line archival storage for retention during the life of the plant.
(d) Identification of the level of authority required to make changes to media, retention, disposition, hardware, software, system documentation and storage locations.

2.3. PROCEDURES FOR RECORD KEEPING

Procedures for managing documents in the RMS should be established and should include methods for verifying the legibility, authenticity, accuracy and completeness of documents. General guidance on record keeping requirements, records management and regulatory considerations affecting its operation are provided in Standard 15489 of the International Organization for Standardization (ISO) on records management [17]. See also ISO Standard 23081 on metadata for records [18].

A major challenge in record keeping anywhere is the decision about which records to retain and which records can be disposed of. As has been discussed above, the importance that is attached to a certain record may change with time and depend on the stakeholder concern.

In some Member States, setting up a system for ensuring retention of the records necessary for decommissioning is considered to be a safety related issue, and is appropriately regulated. For example, the United States Nuclear Regulatory Commission (NRC) formally issued decommissioning rules in 1996 and criteria for licence termination in 1997, while reporting and record keeping for decommissioning planning are addressed in Ref. [19]. For more information, see Annex I–5.

Selection policies and processes for records retention are problematic and need to be continuously reviewed to reflect changing societal expectations, changes in technology, unexpected environmental or human side effects, political expectations and economic changes to name a few such considerations. These changes may mean that some existing archival records may be disposed of or that more records may need to be added to the archives.

Records retention scheduling is the process of developing a document that provides mandatory instructions for what to do with records that are no longer needed. Records retention schedules should as a minimum include:

- Record series;
- Record description, including record title and record number;
- Responsible department;
- Media;
- Date span;
- Hardware and software environment;
- Record formats;
- Copy type;
- Media location;
- Record status;
- Records retention: the length of time records must be retained to fulfil administrative, fiscal, legal, regulatory, insurance, operating, decommissioning and historical requirements;
- The programmes and systems required to process and retrieve these records.

To support the usability of electronic records over their entire life cycle, the retention scheduling process should include the metadata that describe the hardware and software used to store and retrieve electronic records in readable format. It will be necessary to maintain the original software and hardware required to read the information until it is migrated to a new platform. The decision to migrate to a new platform will be made on the basis of the current availability of hardware and software (more details are given in Appendix IV).

Burning, shredding, disposal in an on-site landfill or electronic erasure are approved methods for the destruction of records. For security, proprietary or confidential electronic records, electronic erasure should not be used as the means of destruction. Deleting electronic records will not destroy them, so a more robust destruction method, such as shredding or degaussing, is required. Destruction procedures should ensure that sensitive, proprietary or confidential information is protected and that computer media previously used for electronic records containing sensitive, proprietary, confidential or security information are not reused.

2.4. PHYSICAL MANAGEMENT OF RECORDS

Physical management of records is required in order to keep records in good condition, and to ensure that they remain traceable and retrievable.

Migration is commonly used in the software industry to move records from one system generation to the next. When migrating electronic records, the record format may be changed but its original meaning may still be retained. For example, when migrating a file from Microsoft Word 2000 to Microsoft Word 2006, the text remains the same. However, when dealing with more complex applications, i.e. databases and engineering design systems, this objective will not necessarily be achievable.

Although standards and migration paths may become commonplace at some future date, a large body of digital material exists today in non-standard formats, and operating organizations continue to produce digital material in formats that will require migration. Developing migration standards and reformatting of obsolete material may provide a cost effective method of digital preservation and ensure the availability of records in the future (more details are given in Appendix IV).

Some software applications create backup files with the same names but different extensions to identify them as backup files. These backup files may be recaptured without the need for special utilities. Unless the medium is degaussed or the backup file is erased and its file space either reused or degaussed, the old file may still be resident on the medium.

Books, reports, maps and other hard copy records are typically preserved by placing them in boxes, indexing the boxes and shipping them to conditioned storage. Detailed information on hard copy migration and separation is given in Section 3. Often, hard copies are stored separately from the electronic version, in order to prevent total loss of records in the case of an external event (single failure proof solution).

A records coordinator should ensure that all relevant records have been inventoried and maintained in accordance with applicable laws and regulations. It should also be ensured that contract provisions require the submission of the programme and administrative documentation needed, including background data and technical documentation. Contracts should define which records need to be kept by the contractor for auditing or other administrative purposes and the length of time for which they are to be maintained. It is important to ensure that information be properly transferred during the transitioning of work from one contractor to another, to prevent mistakenly destroying copies of records.

Figure 2 depicts Canada’s general model for the record life cycle, in particular ongoing evaluation activities as a way for ensuring the proper

FIG. 2. Records and information life cycle management (© Library and Archives Canada [20]).

management of records over the long period of time required for decommissioning projects and future generations [20].

2.5. EFFICIENCY AND COST EFFECTIVENESS

The availability of resources must also be taken into account when ranking the various strategic options. A good RMS strategy cannot be implemented if there are no available human resources or if funding is inadequate. Normal funding will not usually allow for complete implementation of changes or enhancements at any one time. The costs associated with locating and retrieving past records are significant as well as the processing costs per record. The availability of resources may be a major issue for many countries. In many cases there are insufficient funds, trained personnel or deployable technologies. A source of funding should be identified at an early stage in the decision making process. A cost–benefit analysis may be conducted. This can identify the lifetime cost of the system, which will include purchase and maintenance. Estimates of long term costs will need to account for routine activities (e.g. surveillance, monitoring and periodic repairs or refurbishment of engineered systems) as well as any periodic large scale replacement of systems (e.g. large capital outlays). Funding for routine activities is often referred to as operational funding; funding for unexpected or unusual needs is often referred to as contingency funding. Because long periods of time may be involved, long term cost estimates also need to take into account the economic factors affected by time (e.g. inflation and 'discounting' to allow for the reduced value of money over time). Given the limitations of the available data, considerable uncertainty will be associated with any long term cost estimates.

However, the benefits of an up to date RMS are obvious, as this improves project execution time and safety, as well as being helpful in planning decommissioning projects and waste removal. In addition, the risks occurring during dismantling projects will be reduced.

2.6. KNOWLEDGE MANAGEMENT

There is a need to document not only the decommissioning record itself but also its context, i.e. the history of its creation, preservation and use through time. Thus, an RMS for management of records will need to contain not only information about a record and the original context of its creation and use but also information about how and by whom the record has been used through time.

The move towards a competitive market, combined with the ageing of the nuclear industry, is leading to increasing regulatory concerns about corporate memory, i.e. the ability of an organization to retain all the knowledge needed to undertake decommissioning. This is particularly relevant to decommissioning projects that include a lengthy deferral period and also to nuclear facilities in countries that have abandoned their national nuclear programmes. Immediate dismantling makes this problem less severe. Comprehensive records of work carried out during decommissioning could also reduce the danger of old mistakes being repeated, lessons learned being lost and inappropriate decommissioning plans being chosen. Regulators are increasingly requiring that operators/owners provide convincing plans, including comprehensive record keeping, training and recruitment, by which continuity of corporate memory can be achieved. Recent experience also suggests that regulators have the same problem of retaining corporate memory within their organizations.

Decommissioning presents significant engineering challenges. Associated generic skills include project management, planning, engineering design, safety assessment and risk management. There is widespread recognition of the ageing of personnel in the nuclear industry. There are not enough younger people being recruited to fill vacant positions. Recruitment is needed over the next decade to replace staff reaching retirement age, the potential shortage being in all roles: engineers, technicians, operators, educators, trainers and regulators. To improve this situation, some countries retain retired experts on a part-time basis [21].

Knowledge management is now a key focus in the nuclear industry and needs to be assessed when considering the information to be maintained throughout the decommissioning phase, for example:

(a) Future decommissioning activities related to the facility, which may occur many years in the future;
(b) Other decommissioning projects related to similar facilities;
(c) Future generations who may want or need the information on the original facility, decommissioning activities and final end state.

The IAEA has recently initiated a programme to deal with the retention of skills and knowledge (nuclear knowledge management). Along with other developments, the changing nuclear workforce is raising issues of the 'knowledge management' underlying the safe and economic use of nuclear science and technology.

In recognition of these and other trends, a number of IAEA advisory committees, as well as the IAEA Board of Governors and General Conference, have called for measures to better identify the nature and scope of the problem, to understand what Member States are doing to address it, and to determine what cooperative international actions might be appropriate.

In response to this challenge, in 2002 the IAEA established knowledge management as an IAEA-wide cross-cutting activity, since all the major programmes of the IAEA are engaged in activities to address preservation and promotion of knowledge and maintenance of competence in nuclear science and technology [22]. Examples of recent IAEA sponsored events are given in Refs [23, 24]. A comprehensive publication in this field is given in Ref. [25]. Appendix I provides examples of other international and national initiatives directed towards the sustainability of nuclear programmes, including decommissioning [26].

3. LONG TERM ASPECTS OF RECORDS MANAGEMENT

To be successful, existing records, data and human knowledge transfer must be continually re-evaluated for integrity and applicability. The records management strategy depends on the expected period of time over which this information must be protected and preserved.

Four main phases can be considered for a deferred decommissioning project:

(1) Pre-decommissioning includes the removal to interim storage or reprocessing of the spent fuel, conditioning and final disposal of radioactive wastes following plant shutdown.
(2) Stewardship preparation includes the site preparation and initial dismantling process.
(3) The stewardship period comprises the surveillance and monitoring activities.
(4) The final decommissioning phase includes all the final dismantling processes, the final survey and all the activities related to licence termination.

Typically, when a decision is made to terminate the licence of a nuclear facility, a new life cycle of the records begins. It is very important to have clearly defined record keeping requirements at this stage to ensure adequate and proper documentation.

Record keeping for a deferred decommissioning strategy involves long term record storage, and, therefore, record access concerns are significantly greater than those for immediate dismantling [19, 27, 28]. There may not be anyone with knowledge of the facility shutdown at the beginning of its deferred dismantling, which may occur up to 100 years or more after closure. Therefore, full reliance will have to be given to the records assembled during the design, construction, operation and shutdown, and personnel should be debriefed at shutdown whenever possible.

Ongoing and rigorous assessment of the records and information must occur to ensure that they are managed effectively over the life of the decommissioning project, ensuring the long term survival of knowledge. Considerations include:

(a) Changing environment and public opinion;
(b) Having multidiscipline teams representing records management, facility management, operations, decommissioning, assessment and planning;

(c) Confidence in safety and cost effectiveness during decommissioning;
(d) Future needs for the records by future decommissioning staff, regulators, stakeholders, the public and national or historical archives.

It is important to emphasize that new information will be generated during decommissioning, including plant changes, inspection results, availability of new technologies and lessons learned from other projects. This information must be captured and included in the RMS, as may be required for future decommissioning activities. In other words, the RMS and its contents should be a living tool and should never be managed as a passive container of information.

3.1. PRESERVATION STRATEGY

An assessment of records identifying the levels of importance, such as 'critical', 'necessary' or 'useful', will be required to determine which documents need the most attention and resources for their preservation. There is a need to manage not only the decommissioning records but also the context of the records, which includes the history of their creation, preservation and use through time.

A records management strategy will help to minimize losses of crucial and valuable information and records, thus ensuring continuity [29, 30]. While loss of records is common throughout the whole life cycle, during the transition phase from operation to stewardship the records are particularly vulnerable. The reason for this is that the records have little or no value to the outgoing operator, and the steward may not have the necessary infrastructure and management structures in place by then to acquire and properly maintain the records. Major losses of records frequently occur when a loss of institutional control has occurred, such as during a period of neglect between the end of active operation and the onset of an orderly remediation programme, or during instances of war or civil unrest.

Experience shows that maintaining some type of activity on the site throughout its life cycle improves the probability of maintaining records. A good solution is to establish a repository whereby all collected records can be maintained until a proper decision on the value of records can be made on the basis of stewardship needs. A concrete example of possible mishaps in transfer of responsibilities for a decommissioning site is given in Ref. [31].

In addition to the operator and their successors, for example, the steward or the regulator may have also collected various types of record. These are often duplicates of records generated or held by the operator and thus provide a certain amount of redundancy. Different rules and regulations for retention may apply for the regulator and other government authorities. Some governments have a well established system for assessing and retaining records. The regulator may require the operator to prepare a summary report on the records held by the operator [2]. It should be noted that laws and regulations might pertain to the general domain of archive management (for Sweden, see Refs [32–34]) or be specific to nuclear records (for Sweden, see Ref. [35]; for the USDOE, see Ref. [36]).

A recommended method to help in the maintenance of records is by incorporating facility records into electronic RMSs. In addition to storing information, electronic record keeping systems are also used to support communication with stakeholders and the public. Several of the databases or inventories listed in Table 1 contain not only information on sites that still have residual contamination above levels of concern, but also sites that have undergone remediation to the current levels of no concern. There is value in retaining information on such sites for two reasons:

(1) They serve as examples or role models for successful implementation of a remediation programme.
(2) The view of what regulators consider a 'level of no concern' can change (and has changed) over time.

Sites that have undergone remediation to standards applicable at that time may now be considered contaminated again, with the more stringent regulations applicable now. In this way, some type of institutional memory of them is preserved.

Keep in mind that records required for decommissioning should be retained in an RMS for the full decommissioning period (which may be 100 years or more) with a view to minimizing damage, deterioration or loss of records. Record maintenance, storage and retention period should comply with national standards and regulations.

Periodic records training should be in place to address awareness and understanding of records maintenance and disposition requirements, as well as the elements of an effective records management programme as a whole. Specialized training in records management may include instruction on records creation and use, filing systems, storage and retrieval, records appraisal, retention, protection, disposition, equipment, supplies and technology.

3.2. RECORDS MEDIA

Procedures should be in place to ensure that information is not lost because of deterioration. Irrespective of the storage media used, consideration should be given to the storage of multiple copies, in several locations with independent protection systems.

The following factors should be considered before selecting a storage medium or converting from one medium to another:

(a) The required life of the decommissioning records, as determined during the record retention scheduling process;
(b) The maintenance necessary to retain the records;
(c) The cost of storing and retrieving the records;
(d) The access time to retrieve stored records;
(e) The portability of the medium (i.e. selecting a medium that will run on equipment offered by multiple manufacturers) and the ability to transfer the information from one medium to another (such as from optical disk to magnetic tape);
(f) User needs.

Since records may have to be kept for very long periods of time, the media used for storage is of crucial importance. On the basis of past experience with record keeping, a few basic requirements on the media and technology for recording can be formulated. Records ideally should be:

— Readable without the aid of proprietary technology;
— Capable of duplication and transfer to new media without loss of content;
— Able to preserve the contextual information surrounding its content and use [2].

The advantages and disadvantages of different recording media are summarized in Table 2. However, as has been discussed above, not all records require long term preservation. Therefore, the choice of recording medium can be made appropriate to the length of the required retention time. Records of only short term relevance may be stored on ordinary office paper or proprietary magnetic media, while records that need to be preserved for a very long term should be maintained on acid free papers, microfilm or other long term media.

TABLE 1. NATIONAL AND INTERNATIONAL DATABASES AND INVENTORIES OF CONTAMINATED SITES [2]

Country	Organization	Name and description
France	ANDRA (Agence Nationale pour la Gestion des Déchets Radioactifs)	Inventaire national des déchets radioactives et des matières valorisables (also contains contaminated sites) (www.andra.fr/publication/produit/RapportSynthese.pdf)
	BRGM (Bureau de Recherches Géologiques et Minières)	BASIAS, inventories of non-radioactively contaminated sites (http://basias.brgm.fr)
	IRSN (Institut de Radioprotection et de Sureté Nucléaire)	GEODERIS, uranium mining and milling sites
Germany	BfS (Bundesamt für Strahlenschutz)	A.Las.Ka, contaminated mining and milling sites
	LfUG (Sächsisches Landesamt für Umwelt und Geologie)	KANARAS, data on enhanced natural radioactivity (including inter alia A.Las.Ka) http://www.umwelt.sachsen.de/lfug/documents/Beitrag_Karlsruhe2006_Boerke.pdf
International	IAEA	DRCS (Directory of Radioactively Contaminated Sites) (http://www-drcs.iaea.org) [37]
Russian Federation	Kurchatov Institute	RADLEG database of contaminated sites (http://www.kiae.ru/radleg)
United Kingdom (UK)	Nuclear Decommissioning Authority (NDA)	Following the advent of the NDA in April 2005, this organization will produce a contaminated land registry for the UK
United States of America (USA)	United States Department of Energy	Legacy Management Sites (http://www.lmldoe.gov/land/sites/sites.htm)
	United States Nuclear Regulatory Commission (NRC)	Power Reactor Sites undergoing Decommissioning (http://www.nrc.gov.info-finder/decommissioning/power-reactor/)
	NRC	Location of Complex Materials Sites undergoing Decommissioning (http://www.nrc.gov/info-finder/decommissioning/complex)

TABLE 1. NATIONAL AND INTERNATIONAL DATABASES AND INVENTORIES OF CONTAMINATED SITES [2] (cont.)

Country	Organization	Name and description
USA	NRC	Locations of Test Reactor Sites undergoing Decommissioning (http://www.nrc.gov/info-finder/decommissioning/research-test/)

Note: Additional information is provided in national contributions (see Annex I).

When the decommissioning records are voluminous or in a fragile state, these choices can prove to be very challenging. However, the following basic steps are suggested as part of an effective archival strategy:

— Identify the different types of records and documents.
— Quantify the volumes of the different records and documents.
— Identify on what media the information is stored.
— Estimate the life expectancy of the different storage media.
— Check whether the digital information currently stored can be transferred to more durable media.

3.3. ELECTRONIC PRESERVATION ISSUES

The rapid evolution of information technology (IT) is creating challenges in managing and preserving electronic records. Complex electronic records are increasingly being created in a decentralized environment and in volumes that make it difficult to organize them and make them accessible. Furthermore, the storage media themselves are affected by the dual problems of obsolescence and deterioration: for example, few computers today have disk drives that can read information stored on 8 or 5.25 in. diskettes, even if the diskettes themselves remain readable. Likewise, the 3.5 in. diskette will soon become obsolete as more and more computers no longer have the capability to read them. These problems are compounded as computer hardware and software applications become obsolete, and they may leave behind electronic records that can no longer be read. Unless these challenges are addressed, valuable information may be lost forever. Knowledge of digital record degradation is still relatively uncommon. For example, it has been quoted [38] that just 18% of UK organizations surveyed had a strategy in place to deal with digital resource degradation.

TABLE 2. TYPES OF MEDIA AND THEIR RESPECTIVE ADVANTAGES AND DISADVANTAGES [2]

Medium	Advantages	Disadvantages
Paper	Easily readable (by the current generation) Long lasting if properly maintained and low acid content Degrades slowly Relatively easy to duplicate Relatively inexpensive	Occupies significant space Inks and paper degrade in the long term Use of poor quality paper or ink can affect longevity Easily destroyed by fire and flood Subject to deterioration by mould or chemical reactions
Film, photographic records	Relatively inexpensive Negatives require less storage space than paper	Media degrade Easily destroyed by fire and water Require equipment to reproduce
Microforms, roll film, fiche and aperture cards	Storage space significantly smaller than many other media Can be read using relatively simple technology (magnifying glasses) Relatively inexpensive Long lasting if properly maintained	Degrade in the long term (although some film media have been developed that potentially last longer than paper) Must be stored under proper environmental conditions Require a tool to read
Digital records	Can be retrieved relatively easily, and rapidly and from a number of areas Storage space (disks, servers, etc.) very small, and one source that is networked can be read by a number of readers Easy to attach metadata Easy to arrange contextually or by multiple contextual relationships Easy to copy	Require specialist software to read Life expectancy of software is very short Relatively sophisticated machines required to access records
Silicon carbide tiles	Very durable in the long term Corrosion resistant Wear and abrasion resistant Do not require sophisticated environmental controls to ensure no degradation	Require sophisticated equipment to form the record (e.g. laser engraving tools) Expensive

In addition, preserving digital information is much more difficult than preserving traditional paper, film and audiovideo information. First and foremost, the long term perspective raises distinctive challenges. Digital archives aim to preserve data for decades, centuries or even longer, and yet the storage media, input and output devices, programming languages, software applications and standards that are necessary to retrieve and interpret digital information are revised and replaced every few years. This is why a reference model for archival systems [39] defined long term as:

> "A period of time long enough for there to be concern about the impacts of changing technologies, including support for new media and data formats, and of a changing user community, on the information being held in a repository. This period extends into the indefinite future."

Additional preservation considerations are given in the Appendix II.

Electronic records may need to be stored in different storage environments on the basis of their expected use and access requirements. For records with high demand, where retrieval time is at a premium, on-line storage in magnetic media may serve best. In a network environment, the information can be stored on-line in multiple locations. An intermediate solution is near-line storage. Where immediate access to information is not needed it can be stored on optical or tape media and loaded onto a DVD jukebox or similar device for archival storage. Little used material may be stored most efficiently off-line, usually in tape format. Digital archives may use any or all of these methods. The most sophisticated systems combine the resources so that objects in use or recent use are stored on-line and, as the information ages it moves to near-line storage and then eventually off-line.

Several factors contribute to the challenge of managing and preserving electronic records:

(a) Massive volumes of electronic data require automated solutions. Electronic records are increasingly being created in volumes that pose a significant technical challenge to our ability to organize them and make them accessible. Managing such large volumes is clearly not possible without automation.

(b) Control of electronic records is difficult in a decentralized computing environment. The challenge of managing electronic records significantly increases with the decentralization of the computing environment. In the centralized environment of a mainframe computer, it was easier to identify, assess and manage electronic records than it is in the decentralized environment, where every user is creating electronic files that may constitute a formal record and should thus be preserved.

(c) Many databases and systems have been developed in-house with codes not available elsewhere, so that special care must be taken to maintain such source codes.

(d) The complexity of electronic records precludes simple transfer to paper. Electronic records have evolved from simple text based files to complex digital objects that may contain embedded images (still and moving), drawings, sounds, hyperlinks or spreadsheets with computational formulas. Some portions of electronic records, such as the content of dynamic web pages, are created on the fly from databases and exist only during viewing session. Others, such as emails, may contain multiple attachments and may be threaded (i.e. related email messages are linked into send–reply chains). These records cannot be converted to paper or text formats without a loss of context, functionality and information.

(e) Obsolete and ageing storage media put electronic records at risk. Storage media are affected by the dual problems of obsolescence and decay. They are fragile, have limited shelf life and become obsolete after a few years.

(f) Electronic records are dependent on evolving software and hardware. Electronic records are created on computers with software ranging from word processors to email programs. As computer hardware and application software become obsolete, they may leave behind electronic records that cannot be read without the original hardware and software.

A recent report on spatial data preservation and archiving [40] reviewed the issues relevant to data preservation. Most new digital media are much less robust than printed books or other paper documents because:

(a) They are less chemically stable than even poor quality paper.

(b) They deteriorate more rapidly even when stored unused in good environments.

(c) Digital data are machine dependent, i.e. they must move within machines to provide their information. Simply reading the data incurs wear on the media.

(d) Digital data are totally system dependent for retrieval of their information. When the system (either hardware or software or both) is no longer sustained, the information will be lost unless it is migrated to a newer system.

(e) Digital information technologies rely on ever greater data packaging densities, making the information ever more vulnerable to large losses from small incidents.

(f) Failure of many newer digital media is often unpredictable and sudden, and may result in total loss of the information held.
(g) For many newer media types, there is little experience with their maintenance and preservation.

Technological obsolescence is a major concern, particularly since technical developments are not driven by and do not take into consideration long term information preservation needs:

(a) Accessibility of digital information depends entirely on intricate combinations of hardware, operating systems, applications software and storage media.
(b) Most systems are heavily proprietary, which leaves those concerned with long term preservation dependent on the market.
(c) Changes in technology are almost wholly driven by business and marketing forces; libraries, archives and other government institutions have virtually no influence on these developments.
(d) Although there are many crucial standards, both formal and de facto, in the digital domain, developments in technology often outpace the standard setting process.

3.4. TECHNOLOGICAL ASPECTS

It is anticipated that the operational RMS, its scheduled maintenance and on-going training of personnel will be transferred to the appropriate decommissioning organization. This provides assurance that existing records and systems cannot only be accessed, but that the procedure for incorporating the new records is provided as well. If these personnel are not transferred to the decommissioning organization, then there is the likelihood that a loss of information from existing records and systems could occur.

Selection of a particular option for the long term management of records for decommissioning depends on many factors, including national legislative requirements and radioactive waste management policies. A variety of means exists for creating and storing information, all of which display characteristics that may either help or hinder its long term preservation.

Regardless of approach, record based information systems may require additional software development and data entry efforts to add/establish cross-reference information to support future retrieval requests. During the collection of the required records, new documents may be created either to resolve discrepancies in existing records or to produce decommissioning project documents as a normal part of activities. See Section 2.4.

Preserving the 'look and feel' of complex objects often requires maintaining the original hardware and software. This requirement may be met by maintaining the hardware and/or software used to create or capture the record; by maintaining hardware and/or software capable of viewing the record in its native format; by ensuring downward compatibility when hardware and/or software is updated, or by migrating the record to a new format before the old format becomes obsolete.

Backward compatibility or migration paths can enable new generations of software to 'read' data from older systems without substantial reformatting. Although backward compatibility is increasingly common within software product lines, migration paths are not commonly provided between competing software products or for products that fail in the marketplace. Thus, refreshing cannot serve as a general solution for preserving digital records. Use of non-proprietary, open software for digital recording should be encouraged to ensure that the ability to view, copy, print and, if appropriate, process any record stored for as long as that record must be retained.

Record copies could be managed more easily if stored as separate records, rather than as combined multimedia records. Any migration can be controlled to ensure continued reliability of the record.

These records will be the subject of frequent retrieval requests; therefore, efficient use of applicable technologies such as imaging storage and retrieval and full text databases to facilitate the retrieval of these records and information should be foreseen. Records availability (location, access, readability, modifications, security and environmental protection) should be ensured at all times.

When choosing an electronic dissemination media (LAN based, Internet based, CD-ROM, etc.), the record managing organization must choose a file format to ensure that information is stored in such a manner that its context is understood in the future and that its authenticity is maintained as well as a method of distribution (posting or transmittal). Several standards have been established and are currently in use, which may serve this purpose, for example:

(a) Graphics:
- — TIFF (tagged image file format), for scanned images;
- — Scanned or other web based images;
- — JPEG or JPG (Joint Photographic Expert Group);
- — PGM (portable gray map file format).

(b) Video:
- — MPEG (Moving Pictures Expert Group).

(c) Audio:
  — AVI (audiovideo interleave).
(d) Text:
  — ASCII (American standard code for information interchange), for plain text documents;
  — HTML (hypertext mark-up language), for Internet/Intranet based documents;
  — RTF (Microsoft's rich text format), for text documents containing special text requirements.
(e) Text with embedded graphics:
  — PDF (Adobe's portable document format).

The choices for optimum migration and dissemination will be impacted by the unique requirements of each Member State or organization, the manner in which they deploy and manage the documents, and by external requirements, including the requirements of the regulatory authority.

Linked records are records that automatically extract information from another electronic file; for example, a word processing report that automatically extracts and displays selected financial data from a budget spreadsheet. Through the use of linked files, one file can be automatically updated when the linked file is changed. This situation would invalidate records that require longer retention periods. Therefore, care must be taken to ensure that the information to be extracted is either copied or pasted into a new record file, or that the file from which data is extracted is protected from being changed or revised. In the former case, copying and pasting data eliminates the need for maintaining the second file as part of the record. In the latter case, any time a component of a set of linked files is changed, the entire set must be saved as a new revision, if required by an approved records disposition schedule. This maintains a revision audit trail for the record through version control.

The RMS must have a classification and indexing system with consistent metadata to ensure future searching and retrieval ability. Irrespective of how complete records are, they are useless if they are not searchable and retrievable.

Document, file and directory labelling conventions should be easily understandable, standardized and documented so that people can find and use the information stored. Additional search and retrieval features, such as full text search or other methods, should be developed to assist the user in locating records.

The systems used to maintain indexes of electronic records should be documented and maintained to ensure identification of, and access to, the records identified. Hard copy codes or identifiers in the form of labels or other products as required should be provided by the system to create unique and complete identification.

The periodic migration of digital records from one hardware/software configuration to another, or from one generation of computer technology to a subsequent generation (migration) should be a basic requirement for any RMS. Procedures should be in place to ensure that information is not lost when new hardware or software technology is implemented. More detail about digital preservation is given in Appendix IV.

Methods for migrating digital information in relatively simple files of data are well established, but the preservation community is only beginning to address migration of more complex digital records.

A variety of migration strategies exist for transferring digital information from obsolete systems to current hardware and software systems so that the information remains accessible and usable. No single strategy applies to all formats of digital information, and none of the current preservation methods is entirely satisfactory. Migration strategies and their associated costs vary in different application environments, for different formats of digital materials, and for preserving different degrees of computation, display and retrieval capabilities. Maintenance of digital data is an expensive process, because knowing what to migrate and preserve requires involvement of subject matter and information experts at the same time.

During the migration of electronic records, there is a range of options for preserving digital information. For example, one might:

(a) Preserve an exact replica of a digital object with complete display, retrieval and computational functionality;
(b) Create a representation of it with only partial computational capabilities;
(c) Generate a surrogate such as an abstract, summary or aggregation.

Furthermore, enhancements are technologically possible through cleanup, markup and linkage, or by adding indexing and other features. These technological possibilities in turn impose serious new responsibilities for presenting digital records to users in a way that allows them to determine the authenticity of the information and its relationship to the original record.

One migration strategy is to transfer digital records from less stable to more stable media. The most prevalent version of this strategy involves printing digital information on paper or recording it on microfilm. Paper and microfilm are more stable than most digital media, and no special hardware or software is needed to retrieve information from them. However, this method will not work with complex digital objects such as GIS (geographic information system) or CAD (computer aided design) drawings, or for video and sound.

Another migration strategy for large, complex and diverse collections of digital records is to migrate digital records from the great multiplicity of formats used to create original digital records to a smaller, more manageable, number of standard formats that can still encode the complexity of structure and form of the original.

Changing format as a migration strategy has the advantage of preserving more of the display, dissemination and computational characteristics of the original record, while reducing the large variety of customized transformations that would otherwise be necessary to migrate records information to future generations of technology. This strategy rests on the assumption that software products, which are either compliant with widely adopted standards or are widely dispersed in the marketplace, are less volatile than the software market as a whole. In addition, most common commercial products provide utilities for upward migration and for swapping documents, databases and more complex records between software systems. Nevertheless, since hardware, software and standards continue to evolve, this strategy simplifies but does not eliminate the need for periodic migrations or the need for analysis of the potential effects of such migrations on the integrity of the digital record.

However, it should be recognized that, in addition to the technical challenges described above, there is a corresponding challenge with respect to the workload and costs involved. In particular, there will be considerable cost in undertaking activities such as migration and the associated QA verification and validation activities required to ensure provenance.

3.5. RECORDS STORAGE FACILITIES

In many countries, the regulations relating to the required records to be collected, maintained and preserved have evolved together with the need for national archives. Existing record keeping practices, which satisfy other regulatory requirements, can provide the adequate basis for records necessary for decommissioning. One example of a standard for records storage facility can be found in Ref. [41].

Strategies to ensure the physical protection of records have been developed. Keeping duplicate records at two or more separate locations is one solution. Given the concern about the longevity and viability of private enterprises and even national institutions, a centralized facility to collect and preserve copies of records should be considered. Having redundant copies of records will also be valuable in the event of a catastrophic occurrence at the place where the original records are kept. One of the locations may even be at the international level, which would offer some protection against the effects of war or civil unrest in a region. Various national and international inventories have been or are being built that collate information on contaminated sites (Table 1).

Within a country, the different types of information pertaining to a given site may be held at different locations, for example, the land register, environmental agency and local authority, which reduces the risk that a complete set of records is lost in a single incident. In a system that is completely dependent on the interaction of various kinds and levels of hardware and software, failure in any one of the subsystems could mean loss or corruption of the records. Effective storage management means making provision for redundant copies of the archived records as protection against loss.

In the case of electronic records, duplicate copies of the records should be required in the event that a recovery is necessary. The copies should be stored in a different location from the on-line copy to prevent possible destruction by the same source that destroyed the on-line copy. Along with the copies of the records, it is essential that copies of the necessary programming and application software be maintained, to help ensure system integrity.

As a minimum, records storage facilities should include vaults, file rooms with fixed fire suppression, fire rated cabinets and duplicate storage. Storage requirements should address the physical damage that could be caused by temperature extremes, moisture, infestation, electromagnetic fields, excessive light, stacking, theft, vandalism, flooding, earthquake, fire or radioactive contamination. Separate storage facilities with the required environmental controls are used for the different media for records (Figs 3–8). See also Appendix II and Refs [41, 42].

FIG. 3. Typical storage facilities for archives, showing records that are well indexed and catalogued.

FIG. 4. A typical storage facility for computer tapes, depicting the required level of environmental controls.

FIG. 5. A storage facility for microfilm aperture cards with a card reader–printer.

FIG. 6. An active file room, showing the use of colour coding to assist in file retrieval.

FIG. 7. A records management application, using optical disk jukeboxes for the maintenance of records.

FIG. 8. A drawing management file room, depicting the proper method for handling drawings.

3.6. RECORDS MAINTENANCE AND PROTECTION

Adequate records management controls should be instituted to ensure proper maintenance and use of records wherever they are located so that all records, regardless of format or medium, are organized, classified and described to promote their accessibility for their authorized retention periods. Records retention schedules and records management controls should be documented in policies and procedures. The controls should include periodic reviews to evaluate the records schedules and to reschedule records as needed. The destruction of records should be subject to explicit written procedures and controls to minimize the risk of losing valuable information.

For the long term preservation of hard copy and microfilm records, it is advisable to make copies of the original records, and to use the copies as the working records. This then allows for the protection and preservation of the original records. When records are moved to an off-site records storage facility, the organization in charge of decommissioning should ensure that they maintain adequate information and a contents list of the record sent to off-site storage.

In addition to preserving records, it is important in many cases to ensure accessibility of the tools needed to access documents, such as microfilm readers and obsolete computer systems.

Consideration should be given to current technological limitations and issues associated with the use of colour for functional purposes, shading and highlighting. Whenever colour is used to designate specific information on records, fidelity and/or comprehension can be lost as the record migrates from one media to another and/or whenever the record is reproduced on equipment without colour capabilities. For example, whenever graphs or flow charts use colour to designate different values or paths of action, the distinction (and consequently the comprehension) will be lost if the records are viewed or reproduced in monochrome or on equipment limited to black and white capabilities. This issue applies to any record regardless of the media. Once the records have been assembled into a single collection every effort should be made to prevent the collection from being dispersed. The records should be maintained in a separate storage facility if possible or at least in a separate room. Access to the records storage facility should be controlled and managed by the records management staff.

To help ensure long term preservation of records, a written, approved, implemented and periodically tested disaster recovery programme is necessary. Implementing an effective disaster recovery programme provides not only for the protection of the records but also helps ensure the immediate resumption of business operations in the event of a disaster. Although the experience in recovering modern media (magnetic tapes, optical media or disks) is very limited, a records disaster recovery plan should exist for all media. Procedures and practices should be established and reviewed to identify means to minimize or avoid potential disasters. For electronic media, disaster recovery backups should exist. In the event of a system failure or disaster, the backup and recovery procedures should provide the capability to restore records, record profiles and any other information required to access the records of the RMS. It is a good practice that any user whose updates have been restored should be notified that a recovery has been executed and they should confirm that the recovery was successful.

The system should provide the capability to rebuild forward from any backup copy, using the backup copy and all subsequent audit trails. This capability is typically used for recovery from storage media contamination or failures.

Control procedures and employee training governing quality records, focusing on guidance for rewriting lost or damaged (e.g. oil-soaked, torn or contaminated) active records, should exist.

Details should be regulated in accordance with national practices. For example, procedures to prevent and control disasters including emergency preparedness, mitigation means, reactions to disasters and recovery for non-electronic media are given in Refs [43, 44].

3.7. DESTRUCTION CRITERIA

During the initial assessment of the records created during the facility's operating period, duplicate copies of both paper and electronic records may be discovered. Some redundancy may be planned to ensure that the more valued records will be available. Once these decisions have been taken, there may still be multiple copies of both paper and electronic records for which destruction should be scheduled.

A general recommendation for paper and many electronic media is to shred the records whenever possible. Although there may be any number of reputable shredding firms, it is advisable to view their operations to ensure that the materials are properly shredded and that the remaining material is properly recycled. Shredding is also frequently the more economic option.

While there are other options for electronic media, such as degaussing of hard drives, achieving compatibility may be expensive. Destruction of other media may be required; reference to ISO standards at the time when destruction takes place is recommended. It should never be considered sufficient to simply overwrite an electronic record.

Post-decommissioning destruction of records should follow the same procedures as those put in place during the initial assessment period. Some records may still remain that will be sent to permanent archives. Before destroying records the following factors should be considered:

(a) The future use of the decommissioned site or land;
(b) Records that could be beneficial to future decommissioning projects;
(c) The historical value of the records;
(d) Financial, legal and environmental liabilities;
(e) Determination of the appropriate time and method of final record destruction;
(f) Retention of the records of destruction in a central archive.

3.8. SECURITY

Documented methods should be established for controlling access to records to prevent loss, destruction or unauthorized alteration. Access control should include:

(a) The identification of the organizational responsibility for authorizing and controlling access to documents;
(b) The identification of the personnel authorized to make changes to documents;
(c) The conditions under which modifications may be made;
(d) The conditions under which decisions about archiving are made.

Access to electronic records must be controlled and managed over time periods that will often exceed the lifetime of individuals, electronic systems and even organizations. Electronic records stored on network file servers are typically better protected and managed, but may still be widely accessible. As a result, security weaknesses may threaten the confidentiality, integrity or availability of electronic information, unless appropriate security procedures are in place.

Four types of document access controls or levels of permission are used by systems: read (browse), write (update), delete and approve permissions.

An effective electronic records security programme implements these in the following ways:

(a) Ensure that only authorized personnel have access to electronic records and information systems;
(b) Provide a capability for electronic signatures or other means of authentication, when required;
(c) Provide policies for determining which documents may exist in other than hard copy form (i.e. electronic or magnetic media);
(d) Prevent unauthorized access, alteration, copying or erasure of electronic records.

Security classification guidance must be sought early in the development of a records management programme. Sensitive information such as confidential personnel data, proprietary information and national security information should not be stored in unsecured environments. Special measures should be taken for the protection of information maintained on removable media. For sensitive or classified data, encryption should be used to protect the information.

Employee access rights should be revoked on transfer, retirement, resignation or termination of the contracts of employees to whom they were assigned. Access identifiers should be associated with specific privileges, such as the ability to retrieve records or to add records to a file. Access privileges should be reviewed on a regular basis. For more details, see Ref. [45]. For more information on recommendations for IT security and hardware considerations refer to Appendix II. Separate requirements exist for the various media types (magnetic media, optical media and CD media), but these are covered in other publications: see, for example, Refs [46–48].

There is in general a global trend towards greater transparency of information for the general public that may require more information to be made public about decommissioning projects, including potentially sensitive data, for example, on spent fuel and waste storage inventories or transportation. With the increase in commercialization of the nuclear industry, the trend is away from national government operation of nuclear activities. This may result in the dispersion of some information, for example that on spent fuel or radioactive waste, as it is not concentrated in a vertical manner at the government level, but is instead held by various organizations in the private sector in a more horizontal manner [62]. In addition, transparency might be in conflict with security requirements and cause some potential concerns related to the reliable preservation and use of records.

To conclude this section, Table 3 provides a comprehensive list of national and international norms devoted to records management.

4. PRESERVATION OF KNOWLEDGE FOR DECOMMISSIONING PROJECTS

The long term nature of decommissioning projects makes it important to carefully identify, collect, organize, manage, protect and preserve the knowledge, related to the full life cycle of the facility being decommissioned, which includes information, records, tools, data, skills and experience. The ability to manage the knowledge is crucial to facilitate the transfer and sharing of this information with current and future generations of decommissioning staff, stakeholders, waste managers and the public.

Knowledge management is defined as an integrated, systematic approach to identifying and sharing an organization's knowledge to enable groups of

TABLE 3. NATIONAL AND INTERNATIONAL STANDARDS FOR RECORDS MANAGEMENT

ISO Standards
ISO 15489-1: Records Management, 1999
Technical Report ISO 15489: Technical Report to Accompany ISO 15489
ISO 18492: Electronic Imaging — Ensuring Long-term Access to Document-based Information, 2004
ISO 23081-1: Information and Documentation — Records Management Processes — Metadata for Records, 2005
Nuclear Information and Records Management Association (NIRMA): Technical Guidelines
TG03-1984: Drawing Management
TG05-1984: Microfilming Nuclear Records on 105 mm Microfiche
TG07-1986: Microfilming Nuclear Records on 35 mm Microfiche
TG10-1988: Management of Safeguards Information (reaffirmed 1997)
TG11-1998: Authentication of Records and Media (reaffirmed 2001)
TG13-1986: Records Turnover
TG14-1992: Support of Design Basis Information Needs
TG15-1998: Management of Electronic Records (reaffirmed 2001)
TG16-1998: Software Configuration Management and Quality Assurance
TG17-1993: Management of Nuclear Related Training Records
TG20-1996: Drawing Management Program Principles and Processes
TG21-2006: Required Records Protection, Disaster Recovery and Business Continuation
PP02-1994: Configuration Management
PP03-1992: Implementing a Configuration Management Enhancement Program for a Nuclear Facility
PP04-1994: Configuration Management Information Systems
Nuclear Energy Institute – Nuclear Information Technology Strategic Leadership (NEI/NITSL) Guidance
NITSL-SQA-2005-1, Policy for Software Quality Assurance in the Nuclear Power Industry

people to create new knowledge collectively, to help achieve the objectives of the organization.

For decommissioning projects, it has been recognized that it is vital that the records be defined, managed and preserved. The nuclear industry has become increasingly aware that to safely and cost effectively manage decommissioning projects it must go beyond the management of records, tools, data and information alone. Those who work in the industry must also understand the context and circumstances in which those records were created in order to reconstruct, understand, apply and use the information.

For example, if only the source code and the data for a computer model are preserved, then the model may not be able to be reconstructed. The following may be necessary to provide future generations with access to the model:

(a) A software compiler for that code;
(b) Software language manuals;
(c) Computer systems, which can run the code;
(d) Design manuals to understand the model;
(e) User guides and instructions on how to actually run the software and explanations on how to understand the results;
(f) In addition to this, experienced, skilled and knowledgeable people capable of understanding and interpreting the model and the results.

Anticipating what future generations will need in one to five years may not be too difficult, but for time frames of 100 years or more, as may be the case with decommissioning projects, the task will be much more complex as more supporting information and context will be required. It is important to understand this since the purpose of preservation is not only to preserve the record but also to document and convey the context and knowledge in which the record was created.

One of the greatest and most tangible threats of loss of information results from organizational change. The nuclear industries of Member States have undergone significant organizational changes in the past and are likely to undergo further changes in the near future.

The risks associated with changes to organizational structures lie in three areas:

(1) Information is lost, destroyed or misplaced during the transfer of responsibilities.
(2) Information is successfully transferred, but its significance not recognized.

(3) The recipient organization operates a different management system with which the recorded information is incompatible.

4.1. INFORMATION PRESERVATION AND KNOWLEDGE TRANSFER FOR DECOMMISSIONING

Irrespective of the perspective, whether short term or long term, the basic cultural principle of decommissioning with regard to future generations applies, i.e. the actions of the current generation should impose no undue burden on future generations. From this premise, the strategy designed to preserve and transfer information to future generations can be developed.

On the basis of the existing core (traditional) decommissioning records required for the future, we must now identify, assess and preserve the supporting knowledge (records, information, tools, skills, context knowledge and experience) that will be necessary to make the core decommissioning records useable for future generations. This will enable future generations to make decisions as to what further action should be taken with regard to the safe cost effective continuity of the decommissioning programme, the physical maintenance of the facility, final end state and knowledge that needs to be further transferred to the next generation.

This will require a systematic assessment and identification of what knowledge must be captured and stored with the records to make them useable by future generations. This would include:

(a) Identifying the knowledge records, skills, techniques, languages, tools, methods and experiences needed by future generations to use the core information, data and records effectively.

(b) Identifying the knowledge, skills and qualification resources required currently for decommissioning activities. This includes resources in decontamination, deconstruction, characterization, hazard analysis, radiological analysis, waste storage, and maintenance.

(c) Developing strategies to preserve this knowledge, which might involve:
   - (i) Developing new information and records to provide the context, history and guidance;
   - (ii) Adding additional information not originally identified;
   - (iii) Developing training programmes for decommissioning specific or other basic required skills at risk of being lost;
   - (iv) Recruiting new staff.

It is the responsibility of each generation to create, maintain and preserve information and knowledge on decommissioning, in a form such that it can be transferred to the following generation. The next generation will require that the information to ensure the decisions are founded on an accurate and reliable understanding of the decommission process.

Further information on knowledge management research and assessments is given in Appendix III.

4.2. HUMAN ASPECTS

Worldwide the nuclear industry is confronting a serious problem regarding knowledge management. In recent years, a number of trends have drawn attention to the need for better management of nuclear knowledge. Depending on region and country, they include:

- An ageing workforce;
- Declining student enrolment numbers;
- The risk of losing nuclear knowledge accumulated in the past;
- The need for capacity building and transfer of knowledge;
- Recognition of achieving added value through knowledge sharing and networking.

Countries with small nuclear programmes are particularly exposed to loss of knowledge. These processes may lead to discontinuity in nuclear knowledge between the current generation and future generations.

Many experts around the world are retiring, taking with them a lot of knowledge and corporate memory. The people retiring everyday are those that can answer questions very easily. They either know where the information is and can quickly retrieve it or have the answers in their heads as tacit knowledge that has never been extracted from them previously.

In some countries, nuclear establishments have not recruited a significant number of young employees for many years. As a consequence, the average age of the nuclear worker has increased, contributing to the ageing of the nuclear workforce. Lack of fresh recruitments has also led to a decline in university enrolment and hiring of new faculty staff.

The gradual loss or degradation of institutional knowledge in the nuclear arena poses a growing threat to the safety and operations of nuclear facilities. A primary purpose of knowledge management is to determine how tacit knowledge might be captured or at least be transferred to successors.

One such concern is the decline in decommissioning skills caused by deferral of decommissioning programmes. This is particularly critical in market driven industries, where resources and skills can be rapidly relocated following changes in industrial trends. For example, in the USA with nine NPP sites undergoing active decommissioning (to be completed by 2010 or so) and with a licence renewal process for operating reactors likely to extend their operations for another twenty years, it is likely that the current level of decommissioning will be significantly reduced, at least for power reactors for a long period of time. Therefore, preservation of lessons learned from decommissioning is a priority in the USA [49].

4.3. TRANSFER OF KNOWLEDGE

Whether or not nuclear power is expanded in the coming decades, it is essential that the nuclear community preserve nuclear scientific and technical competence for the safe life cycle management of existing facilities and applications. Effective management of nuclear knowledge should include:

- Succession and recruitment planning for the nuclear workforce;
- The maintenance of the 'nuclear safety case';
- Retention of the nuclear knowledge accumulated.

Knowledge consists of unique capabilities, skills and experience acquired by an individual or shared by a team of workers. It is stored in the minds of individuals or team members, and is, by definition, not documented anywhere, and this knowledge is inherently difficult to transfer to others.

In the course of a Strategic Human Performance Program of the Electric Power Research Institute (EPRI) a survey was conducted of management and supervisory utility staff and yielded a startling discovery. Nearly 92% of all respondents believed that a loss of unique valuable expertise would pose a problem within the next five years, but only 30% indicated that a planning effort was in place to retain knowledge from experienced personnel and make it accessible and usable by new or replacement workers [50].

Future users of digital decommissioning records will have different needs, expectations, technologies and analytical tools from those that initially created the digital content. This raises challenging questions in the areas of the metadata, semantics and knowledge management technologies that will be required for the future use of records. The economic models for record preservation reflect the fact that the primary beneficiaries of current investments may be future generations. As a result, it is expected that some records will need to be preserved even though their value and usefulness may as yet be unknown. There is a critical need for research and development of methodologies that will sustain electronic records preservation through many downturns in business cycles.

The challenges of maintaining electronic records archives over long periods of time are as much social and institutional, as technological. Even the most ideal technological solutions will require management and support from institutions that in time go through changes in direction, purpose, management and funding. The financial, technical, legal and organizational complexities of migrating digital information over time poses one of the greatest risks for electronic records. Owners or custodians who can no longer bear the expense and difficulty will deliberately or inadvertently, through a simple failure to act, destroy the records without regard for future use. The loss of records and information is a critical factor to be considered, and it is imperative that the proper steps are taken to prevent their loss.

Another risk for information preservation for decommissioning projects is the constantly changing environment. For example, merely the fact that the supplier of major components is from another country may lead to a situation where the language in which the facility documentation was prepared is no longer readable by those operating or decommissioning the facility. As examples, Ignalina NPP in Lithuania and Atucha NPP in Argentina may be given. In the first case, the plant was constructed and operated in the former Soviet Union, where the official language at the time was Russian, and all construction drawings were prepared in the Russian language. After Lithuania was created, all operators were initially fluent in Russian. However, over time, knowledge of the Russian language diminished, and it is expected that in a few years most plant staff will be unable to accurately read plant documentation.

A second example is the Atucha NPP in Argentina. This is a Siemens (German) design, and the construction drawings are in German. This is already a problem for the existing, primarily Spanish speaking, employees and will probably become worse over time.

Information needs will evolve over the long time frame during which preservation will be required. It is not possible to predict accurately what specific information will be needed at the time of actual decommissioning, decades from now. While we cannot presume to understand the needs of the future, we can and should anticipate the types of information that will be needed to protect human health and the environment over the next 20 or 30 years with some degree of accuracy (Fig. 9).

To protect human health and the environment during the long term decommissioning period of a facility, many different types of individual will need to know about the hazards that remain on the site. These individuals include those who are:

(a) Responsible for maintaining barriers and other protective measures on-site, i.e. site stewards;
(b) Using the site or portions thereof for other purposes, such as tenants;
(c) Living or working in off-site areas that might be affected by the hazards that remain at the site;
(d) Community planners and local national officials.

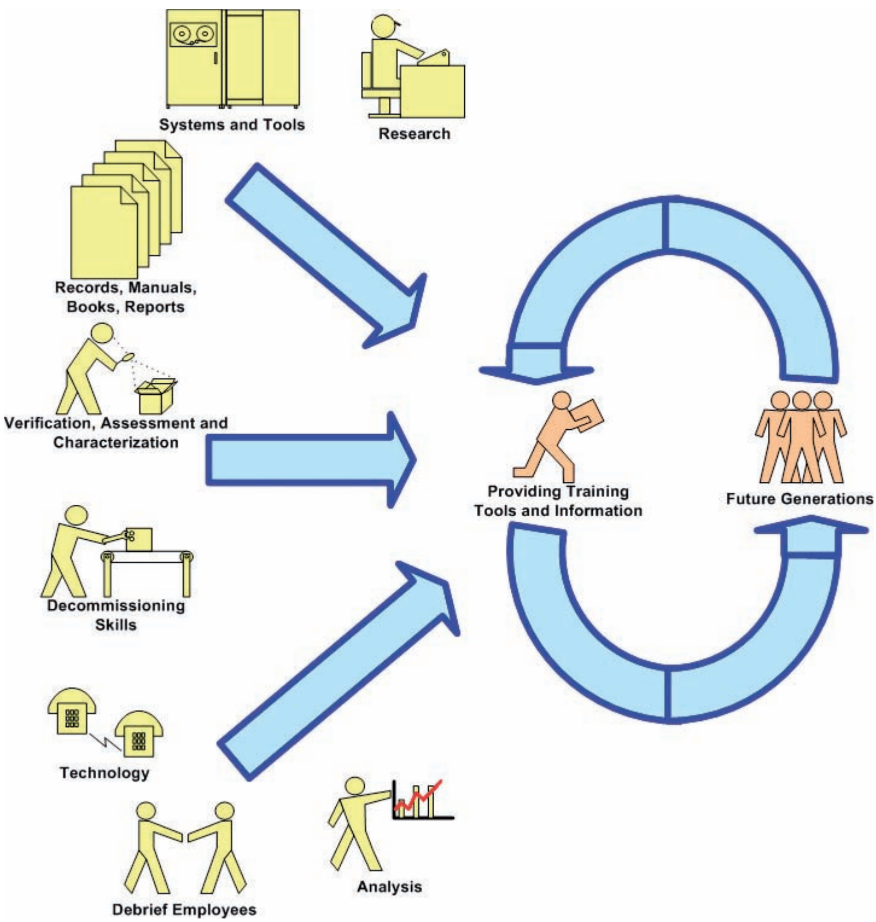

FIG. 9. Relationships between knowledge management and transfer.

Primary protective activities include hazard monitoring and protective barrier maintenance, emergency response and compliance oversight. Ideally, long term monitoring should be designed to identify changing conditions at an early stage, before the protectiveness of the remedy is compromised. All facility areas should be inspected periodically, especially those areas that are sealed or locked, and are not routinely maintained or accessible. The existing information during the period leading to decommissioning should provide adequate input for the required maintenance and inspection activities, which are necessary to ensure that the structures intended to contain contamination remain in an acceptable condition, and that contamination remains under control, does not migrate and that its location, nature and condition are known. Appropriate characterization and documentation should be prepared to provide this information throughout the extended period of deferred decommissioning.

Emergency response activities may involve fire and rescue responses, responding to spills and other chemical or radionuclide releases, or responding to natural disasters such as earthquakes or tornados. Emergencies may directly involve residual hazards on-site (e.g. discovery of new contamination) or may involve such hazards indirectly (e.g. a fire may sweep across on-site areas containing radioactive or chemical hazards). Emergency response personnel should receive special training to ensure that they have the knowledge to respond to anticipated emergencies, and avoid unnecessary risks from potential exposure to residual hazards.

Other related activities include administrative functions, such as resource management, planning and economic development activities. Some of these activities are not likely to be conducted by the site stewards, but rather by others using, or concerned about, the site. However, the information produced by these activities will remain an integral component of long term stewardship.

Other users of information include local, regional or national entities that are responsible for performing or overseeing stewardship functions at a site and providing administrative support for those activities. Users external to the site include emergency response personnel and community planners.

The use of existing plant systems and components during the preservation phase is a special issue. Systems that are necessary for lighting, monitoring, ventilation, fire protection, etc. will require periodic attention and maintenance or they may not be suitable for safe operation when reactivated. If they can be eliminated and portable systems used instead, costs may be reduced. Another example would be that if electrical systems are old or their condition unknown and requiring significant work to meet code requirements, then it may be more economic to use temporary electric power sources. Similarly, use of portable compressed air systems may be more economic than maintaining old systems for several decades. Conversely, equipment that is planned to be used for future decommissioning work, such as cranes, must have scheduled maintenance and inspections.

Tasks that monitor or maintain systems no longer needed for safety purposes or disposition activities should be discontinued. Tasks implemented during this phase are intended to support preservation activities and to maintain the facility safety envelope and long term requirements on building infrastructure, including modification and/or changes to facility configuration.

The hazards associated with planned decommissioning work activities should be well documented. It is important to identify hazards that are created or exacerbated with time; for example, when facility structures may deteriorate. In such cases, precautions should be taken to ensure that unassessed or uncontrolled risks are not created. Although monitoring will be an important element of long term stewardship, unexpected deviations or failures can be expected to occur. For example, engineered controls may fail to contain contaminants or waste, or unknown sources of contamination may be discovered.

Personnel who use, or supervise the use of, procedures or equipment infrequently may need to be retrained or briefed prior to performing these tasks. The need for ongoing training will be necessary. A programme should be established whereby personnel are periodically trained to operate equipment, manage facilities, and manage records and information.

5. CONCLUSIONS AND RECOMMENDATIONS

Information about a nuclear facility spans the entire life cycle of the facility, from the planning stages through construction and licensing, operation, shutdown, possible safe enclosure, eventual decommissioning and for some period beyond. Each of these stages could last for decades. In anticipation of the eventual decommissioning, a rigorous assessment of the records (and additional supporting information that has been created) should be performed. A good RMS will be more easily transferred to and utilized by the future dismantlers than a poor one. In addition, the initial assessment should only be considered the first of many. Preservation and protection strategies must be developed, including a QA programme that incorporates scheduled reviews of the records, including anticipated migration schedules designed to ensure that the integrity of electronic records is required.

The following recommendations are grouped according to the four major technical areas introduced and discussed in this report.

5.1. RECORDS PRESERVATION OVER TIME

Records and information must be managed and maintained to be available when needed. Long term preservation of record media and the ability to access records and information are essential to the success of decommissioning projects.

The recommendations we make are:

(a) Create a long term proactive records information management plan: commencing with an information audit, once the size of the problem has been determined, proper resources should be made available for the task of creating a solution (with clear responsibilities assigned).
(b) Consider the long term value of records when putting together plans and budgets.
(c) The RMS should utilize electronic record keeping tools, such as EDMSs and RMAs to support the records management strategies.
(d) Records storage and protection strategies should include safe and secure storage facilities, duplicate copies of electronic records, electronic RMSs and RMAs.

5.2. PERIODIC ASSESSMENT OF RECORDS, AND CRITERIA FOR THE ASSESSMENT FOR LONG TERM PRESERVATION

The long term preservation of records is paramount to the success of any decommissioning project. In order to ensure the long term survivability of records and information, the records must be assessed not only when they are acquired but also at least annually thereafter.

The recommendations we make are:

(a) Periodic audits and inspections of systems, applications, media and processes should be made and documented to ensure prevention of data loss.
(b) The long term preservation characteristics should be considered when selecting records management tools and technologies.

(c) The collection, safekeeping, retention, migration, maintenance and updating of decommissioning records should be an integral aspect of the facility QA programme.

5.3. RECORDS TRANSFER AND SHARING

The records and their associated metadata will need to be accessed by a wide variety of stakeholders over time, from regulators to operators and from decommissioning staff to environmental agencies. As a result, the records need to be in a form that facilitates reliable and efficient transfer of information over an extended time frame.

In order to achieve this, the recommendations are to:

(a) Carefully evaluate the long term technology considerations associated with formats, media, migration and indexing of records, and of developing and implementing an RMS.
(b) Consider the long term preservation characteristics of the file formats and storage media, working with other organizations and with software/hardware vendors to encourage the development of open standards [51].
(c) Regulatory bodies need to work within their sectors and the record preservation community, to map out a framework to allow organizations to store information in an exploitable form while retaining the ability to satisfy regulatory concerns. This will facilitate the spread of knowledge within the nuclear community [51].

5.4. LONG TERM TRAINING AND COMPETENCE BUILDING

Worldwide, the nuclear industry is confronting a serious problem regarding knowledge management. In recent years, a number of trends have drawn attention to the need for better management of nuclear knowledge. Depending on region and country, they include:

- An ageing workforce;
- Declining student enrolment numbers;
- The risk of losing nuclear knowledge accumulated in the past;
- The need for capacity building and transfer of knowledge;
- Recognition of achieving added value through knowledge sharing and networking.

The recommendations are to:

(a) Identify the knowledge records, skills, techniques, languages, tools, methods and experiences needed by future generations to fully understand and use the core information, data and records effectively.
(b) Identify the knowledge skills and qualification resources required at present for decommissioning activities. This includes decontamination, deconstruction, characterization, hazard analysis, radiological matters, waste storage and maintenance.
(c) Capture and preserve by a proactive knowledge management programme the context and environment in which records are created.
(d) Develop strategies to preserve this knowledge, which might involve:
    (i) Developing new information and records to provide context, history and guidance;
    (ii) Adding additional information, not originally identified;
    (iii) Developing training for decommissioning specific or other basic required skills at risk of being lost;
    (iv) Recruiting new staff.

Appendix I

INTERNATIONAL AND NATIONAL INITIATIVES FOR SUSTAINABLE NUCLEAR PROGRAMMES

I.1. DEVELOPMENTS IN EUROPE

The following paragraphs provide examples of other international and national initiatives directed towards sustainability of nuclear programmes including decommissioning [26]:

(a) Recognizing the problem of nuclear industry ageing, and the necessity to undertake active efforts in strategic planning of education and human resources, the Russian Federation created Minatom in 2002, a Working Group for comprehensive analysis of the situation and development of a special programme (Green Vector).
(b) The OECD voiced their concern about ageing in their report 'Nuclear Education and Training: Cause for Concern?' [52], which contained the recommendation that "Governments should engage in strategic planning of education and manpower, integrated with human resource planning, to encourage young students into the industry." However, young people are only likely to choose such a career if there are reasonable prospects of future employment. An OECD Nuclear Energy Agency follow-up report is given as Ref. [53].
(c) European Union programmes in this field are described in this paragraph. The primary aim of the EUNDETRAF project is to pool knowledge and expertise in the field of nuclear decommissioning of acknowledged European experts and then disseminate it, mostly through training courses, to the wider nuclear industry to improve safety standards and European competitiveness. EUNDETRAF is a consortium of eleven European organizations representing educational establishments, nuclear industry operators, R&D organizations and regulatory bodies [54]. Of particular concern to the European Commission are the special skill base deficits within nuclear radiological protection, radioecology and radiochemistry at masters and doctorate levels. The European Academy Bolzano (EURAC) will strengthen the scientific academic competence and analytical skills within the aforementioned fields and secure future recruitment of appropriately skilled postgraduates to meet the needs of European stakeholders. At university teaching level, the European Nuclear Education Network (ENEN) has

been created. ENEN resulted from the cooperative action of ENEN partners (universities and research institutes) from 16 countries under the EURATOM fifth framework programme (FP) [55]. Under the sixth FP, the NEPTUNO project will further the integration and qualifications provided by university courses in nuclear disciplines at European universities and enhance harmonization of professional accreditation criteria and associated training programmes across the European Union.

(d) The UK Nuclear Decommissioning Authority (NDA) will work with others to evaluate the potential for a national nuclear skills academy and a nuclear institute; a national graduate scheme that will work in partnership with agencies and providers across the UK to develop locally specific provisions. The NDA will also contribute to the UK Government's review of the case for a National Nuclear Laboratory and work with the Government and others to implement whatever decisions are made. Finally, the NDA will create a national nuclear archive to act as a central resource to the UK nuclear industry. The nuclear skills academy will be a world class centre of excellence in nuclear skills development, providing education, vocational training and business support. It will be a bridge between learning and employment, and is one of a number of initiatives to create a world class nuclear decommissioning industry in West Cumbria and across the UK.

(e) The skills needed by the UK industry over the next 10–15 years had to be considered — this timescale being necessary to address root causes and training lead times. The needs assessment will be used to inform those engaged in planning (in industry, academia, education, professional institutions and Government) of potential skills shortages; and thereby the recruitment, education and training needed to avert those shortages.

(f) Human resource planning was a key priority. The report estimates that the UK nuclear and radiological sector will require 50 000 engineering and health recruits over the next 15 years. This finding develops from present industry age profiles plus expected growth in demand for health and nuclear cleanup skills. Of these recruits, 15 500 (i.e. about 1000 per year) will need to be engineering and physical sciences graduates.

(g) Some initiatives have already been taken in the UK to address the need for more nuclear recruits: notably the creation of the Nuclear Technology Education Consortium (NTEC). The NTEC represents over 90% of nuclear teaching expertise in the UK and aims to meet the UK's projected post-graduate nuclear skills requirements in the areas of decommissioning, reactor technology, fusion and nuclear medicine [26]. Another initiative is the Young Generation Network (YGN) of young engineers and scientists established in the UK by the European Nuclear

Society. It has been established as a national network of professionals within the ‘younger generation’ members of the British Nuclear Energy Society (BNES) who are willing to make efforts to raise their awareness of the industry as a whole and learn from the experiences and knowledge of mature established professionals.

I.2. THE KNOWLEDGE MANAGEMENT PROGRAMME OF THE UNITED STATES NUCLEAR REGULATORY COMMISSION

The following description of the NRC’s knowledge management programme has been drawn from an official NRC policy information paper [56].

The NRC is a knowledge-centric commission that relies on its staff to make the sound regulatory decisions needed to accomplish its mission. In the recent past, the NRC has enjoyed a stable workforce and a climate of slowly evolving technologies, which has allowed it to meet its performance goals by using an informal approach to knowledge management. That environment has now changed, and the NRC must now institute a systematic approach to knowledge management that can support the faster rate of knowledge collection, transfer and use needed to accommodate increased staff retirements, mid-career staff turnover, addition of new staff and the broader scope of knowledge needed to expand the NRC’s knowledge base to support new technologies and new reactor designs.

Knowledge management is a contemporary term. However, the concept and practice of knowledge management are not new at the NRC. The commission, since its inception, has maintained and continuously improved the individual capabilities of its staff through numerous methods designed to transfer implicit and tacit knowledge, such as formal classroom and on-the-job training, structured qualification programmes, informal communities of practice, mentoring, creating dual-incumbent positions and other formal development activities. The NRC has also maintained its organizational capabilities or structural knowledge largely in the form of explicit knowledge: job aids and desk references, written policies and procedures, regulatory guides, standard review plans, NUREG guides, regulatory issue summaries and statements of consideration for making rules.

A well designed knowledge management programme can return significant value to the NRC by providing a systematic approach for identifying, collecting, transferring and using the staff’s relevant critical knowledge. Offsetting the realizable value obtained through knowledge management is the cost imposed as a burden on the commission’s staff to develop, learn and apply the knowledge management principles and practices necessary to effectively implement and execute the programme. In order to maximize the knowledge management programme's value proposition, it is important to minimize the burden on the staff by integrating knowledge management into the commission's business processes and technology, rather than by approaching knowledge management as an additional or ancillary requirement that exists outside the scope of normal work.

Ultimately, the effectiveness of knowledge management requires it to be an integral element of the NRC's work. Integrating knowledge management will require staff to think from a knowledge management perspective when designing workflows and to look beyond performing only the task at hand to considering how the NRC's knowledge can be captured so that it is shared into the future. This fundamental change in perspective will require top–down support from senior managers in the form of clear expectations, adequate resources and rewards for the desired behaviours and results.

In order to implement an effective long term knowledge management programme the NRC must also create a sustainable environment for knowledge retention by leveraging existing processes and technology to the maximum extent to:

— Identify and prioritize critical knowledge;
— Recover and collect that information;
— Transfer, store, access and use the information.

Leveraging existing processes allows staff to build on what they are already doing and to connect these familiar processes with the newer concepts of knowledge management. More importantly, staff must be both allowed and expected to share and transfer knowledge as a normal part of their work for the NRC.

Implementing an effective long term knowledge management initiative and integrating it into the NRC's day-to-day routine requires fundamental changes to its organizational culture. Although benefits of the knowledge management initiative can be realized immediately, fully institutionalizing changes of this nature typically requires a period of several years. Because of the significance and duration of the change process, active change management is essential to the success of knowledge management at the NRC. Managing the changes will require clear communications, both top–down and bottom–up alignment, building momentum on early successes, and, most importantly, leadership to direct the effort over the long term.

In October 2005, NRC senior management conducted an in-depth meeting to address knowledge management issues, which resulted in two important outcomes. The first was an agreed upon working definition of knowledge management — knowledge management is a continuous, disciplined and timely process of identifying, collecting and using information to better accomplish a task. The second was the identification of the following four key action items that are necessary for implementing an NRC knowledge management programme to consolidate and expand the ongoing knowledge management activities of the commission's offices and regions.

(1) For successful implementation, the NRC's knowledge management programme must have explicit visible structure and governance. To that end, the Deputy Executive Director for Materials, Research, and State and Compliance Programmes (DEDMRS) has been designated the commission's knowledge management champion for overall leadership, direction and integration of the knowledge management programme. Each office director and regional administrator has named a senior manager who will lead the development and implementation of knowledge management activities within their organization. The DEDMRS will form a steering group of office and regional knowledge management champions to provide cross-communication and integration of knowledge management initiatives. Each office director and regional administrator will also appoint a senior staff knowledge management leader, who will assist in the implementation of specific knowledge management initiatives. The Office of Human Resources will provide programme support, coordination and evaluation.

(2) The offices and regions are tasked with identifying occupational priorities of NRC staff and critical bodies of knowledge where knowledge management is most needed in their organizations. The occupational priorities are those positions where the office or region is most likely to lose significant relevant knowledge in the near term. The critical bodies of knowledge are technical and administrative areas of expertise where knowledge management techniques are most needed to avoid losing significant mission-critical knowledge. The occupational priorities and critical bodies of knowledge identified by inputs from the offices and regions will be compiled into a consolidated list to inform and direct the NRC's knowledge management efforts.

(3) The staff will develop a set of knowledge management standard practices and techniques from which the offices and regions can select the tools best suited to their own individual needs. Standard practices and techniques include mentoring, formal training and qualification programmes, policies and procedures, regulatory guides, standard review plans, job aids, best practices, and information technology and

information management solutions. A number of offices and regions have already developed their own knowledge management initiatives. The NRC's knowledge management programme will integrate these and other initiatives across the commission to ensure that the staff has a common set of tools to effectively and efficiently perform their jobs.

(4) The staff will investigate and explore innovative information technology and information management tools that the NRC may incorporate and acquire to support knowledge management and help achieve the Expanded Electronic Government strategy to make it easier for NRC employees to acquire, access and use the information needed to perform their work. These tools may include content management systems, information portals and 'Google-like' indexing and search programmes designed to make existing information available to all staff in a user-friendlier manner. Additionally, some existing tools, such as the Strategic Workforce Planning (SWP) system, may need expanded capabilities to meet the NRC's knowledge management requirements. In cases where knowledge that is critical to the commission's regulatory mission exists primarily outside of the commission, such as new reactor designs, information technology tools will need to be employed that provide connectivity between the staff and external knowledge resources.

The NRC's knowledge management framework is illustrated in Fig. 10, and identifies the what, why and how of the NRC's knowledge management

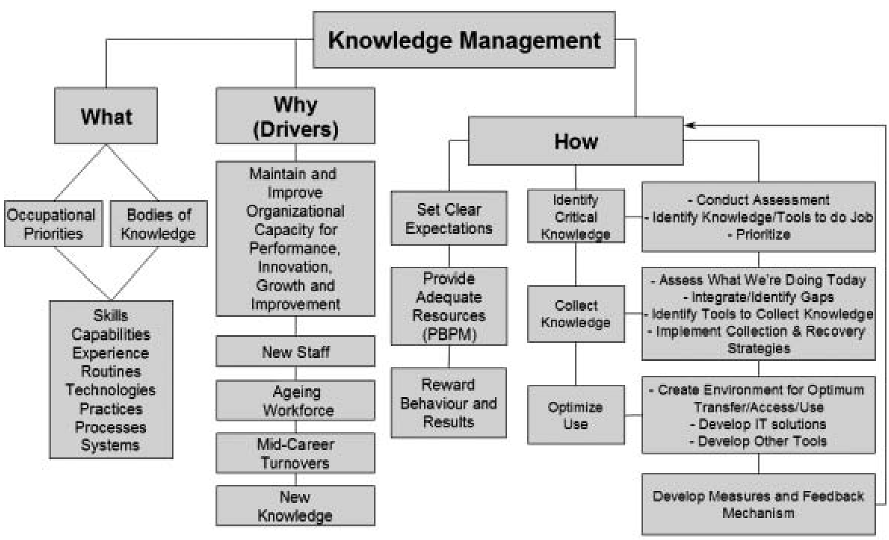

FIG. 10. The NRC knowledge management programme.

programme. The 'what' determines the programme's primary focus, which is on the occupational priorities and critical bodies of knowledge. This represents the knowledge whose loss creates the greatest negative impact on the mission of the NRC and provides the first of the two dimensions used for prioritizing efforts: importance. The 'why' identifies the factors driving the need for knowledge management within the NRC. In the context of the framework of the knowledge management programme, the 'whys' help identify either the existence or imminence of gaps in the NRC's critical knowledge, which provides the second dimension used to prioritize efforts: timeliness.

The programme framework addresses ways in which to accomplish the desired knowledge management programme outcomes described above. The first is implementation of the programme in terms of:

— Setting expectations for management and staff;
— Providing adequate resources either by adding new resources or shedding lower priority work;
— Rewarding knowledge-sharing behaviour and successful programme results.

The second is conducting the programme to:

— Continuously assess the NRC's critical, relevant, knowledge;
— Identify appropriate tools for knowledge management;
— Apply those tools to collect, transfer and use knowledge in an optimal fashion;
— Gather feedback to improve the programme's efficiency and effectiveness.

The process for collecting, transferring and using knowledge is designed to be an iterative and continuous process that provides the programme with the inherent ability to adapt to changes in the regulatory environment, both now and in the future.

Knowledge management, like financial management and personnel management, has always been an inherent responsibility of NRC's managers and supervisors. The highly stable nature of the NRC's workforce in the past has allowed managers to devote less time and focus fewer resources on the knowledge aspect of managing the NRC than on the other aspects. Consequently, many knowledge management activities have been identified as lower priority activities — not because they were considered unimportant but because the stability of the NRC workforce provided an option to defer them until a later time.

For the reasons cited earlier in this Appendix, most notably the change in the NRC's workforce, continually deferring knowledge management activities is no longer a viable option. Managers and supervisors now need to actively engage in knowledge management by prioritizing the NRC's knowledge management activities over other NRC activities and allocating the necessary resources to knowledge management through the planning, budgeting and performance management (PBPM) process. In the short term, the involvement of supervisors and senior staff in knowledge management activities may result in the PBPM process deferring some direct effort activities: for the long term, the NRC may need to reassess employee to supervisor ratios and the budget models used to determine hours of direct work.

Appendix II

ADDITIONAL MEDIA AND HARDWARE CONSIDERATIONS FOR LONG TERM PRESERVATION FOR RECORDS

Documents must be in a form matched to their retention classification. For example, typical documentation is printed on regular paper that has a lifetime of the order of a few decades [57]. If the information in some of these documents is to be retained for the anticipated length of the long term decommissioning project, the documents, or the information they contain, will have to be converted into a form suitable for long term information management. The storage media must have a life expectancy at least equal to the applicable record retention period, unless there is a quality transfer from one media to another with no loss of data.

(a) In general, handmade paper not containing wood pulp can be regarded as permanent for a period of around 1000 years. The longevity of wood pulp is much less, but any high quality paper can be stored, retrieved and read for at least 20 years, if not a century. Even newspaper clippings endure for 10–20 years. At the present time, the good quality copying paper widely used in combination with accepted copiers and printers is considered adequate, so that there is no reason for a large scale transfer of decommissioning information from paper to any other archive medium if this is not justified by other record management principles. The quality of coated and uncoated paper used in the production of publications and documents acquired and retained by libraries and archives is regulated by national standards, for example, in Ref. [58].

(b) In addition to concerns about the long term stability of the base medium, the stability of the actual inscription and possible detrimental interaction of the chosen materials or techniques with the base medium need to be assessed. It is known, for instance, that certain inks will fade or destroy paper due to chemical reactions. The preservation of written records on organic fibres, such as papyrus leaves, or on prepared animal hides (vellum) for several thousand years indicates their long term stability. Inks that form a stable inorganic compound (e.g. iron gallate and soot) after the medium has evaporated are preferable over those that rely on, for example, organic polymers. The cheap modern papers and computer inks that seem to be in general use at present to produce hard copy records are a concern.

(c) Paper remains a very popular medium for records. Most papers display qualities suitable for long term preservation, particularly if they are stored in a controlled environment. The appropriate conditions for long term preservation of paper can be readily achieved given modest resources. Additional measures may also be employed, including restricting direct access, the use of lint-free gloves when handling records, and the elimination of metal and plastic items such as staples, paper clips and PVC covers, all of which can have a detrimental effect on paper longevity. With the ever increasing pressure to use 'environmentally friendly' processes, however, the use of recycled paper is now commonplace, despite the unpredictable nature of its long term performance. Paper must be stored under environmental conditions that prevent active growth of mould. Exposure to moisture through leaks or condensation, relative humidity in excess of 70%, extremes of heat combined with relative humidity in excess of 55%, and poor air circulation during periods of elevated heat and relative humidity are all factors that contribute to mould growth. Paper records are relatively bulky, requiring large and costly storage facilities. Documentation of the decommissioning of a typical NPP takes up about 1500 m of storage space for A4 size pages.

(d) Microfilms have been a popular medium for many years where such large volumes of data, drawings and diagrams require preservation. Microfilm has been estimated to have a life of around 200 years and, if maintained in a climate controlled environment, it can last for 500 years. As film may be copied four times, without significant loss of information, information on microfilm may be preserved for periods much longer than those required for any decommissioning project. However, it is noticeable that, with the increased use of electronic data storage systems, the popularity of microform has declined. Continuing improvements in film construction and the introduction of laser printing techniques, combined with its long term stability and competitive cost, suggest that this medium has the potential to feature in future decommissioning information systems.

(e) Printed matter represents human thoughts by the use of a stock of symbols. In contrast, an audiovisual document is an analogue representation of a physical status or event: every part of such a document is information. While a speck of mould in a book does not normally hamper the understanding of the text, comparable damage on a photograph would cover up information, and, on a magnetic tape, it could even render the tape unreadable. Viewed, therefore, from the perspective of redundancy, audiovisual documents require a higher degree of protection and security than written materials. Digital data can also be similarly endangered.

(f) One factor that most, if not all documents, have in common is their reliance on polymeric materials, all of which decay. This decay cannot be stopped, but it can be slowed down by careful handling and favourable storage. Decay can also be greatly accelerated by careless handling and poor storage.

(g) Although use of high quality branded media may double the above life expectancies, these media/systems require a controlled environment for storage, and the records retrieval and replacement methods used in such systems are slow and labour intensive, and may lead to misfiling or loss of data.

(h) Analogue data stored on magnetic disks or tapes was the principal storage medium used until the mid-1980s. Much important historical information resides on these media and, while our understanding of the long term characteristics of the media is less well advanced than that of paper, there is a fairly substantial knowledge base. According to manufacturers' data sheets and other technical literature, thirty years appears to be the upper limit for magnetic tape products, including video and audiotapes [46].

(i) The subsequent development of optical media saw a move away from the relatively error-prone and delicate magnetic media. On first inspection, it appears as though the robust and seemingly indestructible nature of optical disks provides an ideal storage medium to complement the information system architecture for the long term. However, there is relatively little experience in their use and, consequently, we possess limited knowledge of their evolutionary characteristics and suitability for long term preservation of information. Optical disks, compact disks or digital videodisks allow comprehensive storage and indexing but require controlled environments and transfer of older records to electronic forms, and regulatory authorities often refuse to accept optical media as the sole record storage method.

(j) The past twenty years has seen a significant increase in the use of electronic systems for recording data. The convenience, potential storage capacity and low cost of these storage media make them an attractive alternative to paper or microform based systems, but the fact that most electronic hardware is not expected to function for more than 5–10 years raises very serious problems for long term archival preservation. A review of the current activity in the field suggests that the manufacturers of data storage systems have not yet developed a business model for long term, as measured in multiple decades, storage. Integrated circuits, thin film heads and laser diodes cannot be repaired now, nor can they be readily fabricated, except in multimillion dollar factories. There have been, for many years, important products for data backup and restoration, and there are products available now for information life cycle management and disk-to-disk based solutions. However, these products have limited lives and limited guarantees, and generally are replaced by newer generation products with lives of three to seven years. When this replacement is effected, the data are migrated from one (often proprietary) system to another, and the solutions implemented for that migration are tailored to a specific manufacturer and time period, and are generally labour intensive and address specific types of digital object.

(k) This situation, where industry has provided satisfactory limited period solutions, has been facilitated by the increases in storage capacity and the corresponding decrease in cost of raw storage. However, the management costs associated with storage systems now vastly exceed the hardware costs. Furthermore, if the volumetric storage density growth rate slows significantly, while the data created continue to expand exponentially, the cost of augmenting storage capacity becomes high. To summarize, it has been noted that there is an "absence of proven archival solutions". There is little known about how reliably contemporary media will hold data over time. Over a 10–20 year period, data can be corrupted or disappear. Magnetic tapes have been and are being widely used for backup and recovery, as well as for archival purposes, but have high maintenance requirements. Early magnetic tapes began to lose oxide within seven years [47]. Anecdotal evidence about recovering data from tapes, which were kept off-line for 15 years or more, showed limited recoverability of about 70% of the records. At the Rochester Institute of Technology, files stored on 8 in. flexible diskettes from 1970s era word processors are unreadable — not because of their condition but because readers for that medium are unavailable. Forty-four megabyte Syqest disks from the 1990s are about to suffer the same fate. Libraries and information repositories face a continuing challenge in maintaining files on currently supported storage hardware and media and in currently supported file formats for currently supported operating systems that require structured data organization [46].

(l) Very few, if any, life expectancy reports for these disks have been published by independent laboratories. An accelerated ageing study by the US National Institute of Standards and Technology estimated the life expectancy of one type of DVD-R disk to be 30 years if stored at 25°C and 50% relative humidity [48].

(m) The following gives an overview of the various media available and the relative advantages and disadvantages of each, while Table 4 contains a brief overall summary:

  (i) Normal paper — This is still the most common medium for existing records, but it cannot be expected to have a life longer than a few decades, mainly because of the acidity of pulp. The advantages of

TABLE 4. POSSIBLE LIFE SPANS OF DIFFERENT ARCHIVAL MEDIA AND THE CLIMATIC CONDITIONS REQUIRED FOR THEM

Medium	Lifetime (a)	Temperature (°C)	Relative humidity (%)	Light (lx)
Paper	Hundreds	<18	30–40	<50
Microfilm	Up to 500	<15	25–35	
Magnetic/optic	Approx. 10	<18	35–45	

this medium are that it is already in a form suitable for storage, it is readable without tools and it copies easily. The disadvantages are that it may not meet the requirements of being readable during the institutional control phase of a few hundred years and that it is a relatively bulky medium requiring large and costly storage facilities.

(ii) Permanent paper (ISO standard [24]), which has an alkali reserve, has a life of several hundred years if conserved under specified conditions (no light, low relative humidity and temperature, minimal handling and acid-free physical contact) [59]. The advantages are that it is directly readable and easy to copy, although it is necessary to study the characteristics of the paper and printing material combination (inks).

(iii) Microfilm – This medium can be expected to have a life of 100–200 years (when properly stored in an appropriate climate). Microfilm as a replacement for paper documents was introduced on a large scale in Western European countries and the USA during the 1950s. The advantages are that it has a relatively small volume for a given storage capacity and that it can be read directly with simple magnifying tools. The disadvantages are that special tools are required for copying to other media. The maximum number of replications of the microfilm itself is considered to be four, and there are requirements for minimum handling. Another disadvantage is that transfer of information from microfilm to other media has been shown to reduce the quality and readability of the output information.

(iv) Optical disks — This new medium can have a durable lifetime in excess of 100 years. Its advantages are a large storage capacity, widespread use, and rapid retrieval and copying capabilities. Its current evolution in the market seems to show that it has a promising future in the short term. The biggest disadvantage of optical disks is the uncertainty in their readable life, since their readability is completely tied to the availability of the tools that can access the information they contain. Currently, the readable life of optical disks must be considered to be of the order of five to ten years, the expected available life of the tools required to read them.

(n) Specialized media — With the increased recognition that there is a need to preserve selected information related to radioactive waste for periods of time in excess of those traditionally associated with records management, some organizations have developed specialized media. An example of a system that has recently been developed but is not yet a proven technology for archiving is that of laser engraving data onto silicon carbide tiles. Studies carried out during research have suggested that silicon carbide is an extremely durable material that is very strong and is resistant to corrosion and wear from abrasion. The use of precision laser engraving has enabled the issue of quantity to be addressed — an early trial of the system demonstrated that information contained in 500 pages of an A4 sized report could be transferred onto 42 silicon carbide tiles measuring 10 cm × 10 cm × 1 mm. The durability of the silicon carbide medium suggests that it would be possible to preserve documents without the need for sophisticated preservation environment controls, further migration or other human intervention for at least 1000 years [10].

(o) Recovery of the information is relatively straightforward using appropriate magnifying equipment. An alternative approach to recording the information in common text is to inscribe digital information converted to analogue form directly onto silicon carbide tiles as an alternative to microfilm. An extension to this, which echoes back to the strategy used by the creators of the Rosetta Stone, is to provide dual transcription where the information is provided in both digital (in binary code) and human readable textual form on the same tile.

(p) As technology continues to progress it is conceivable that other media and recording systems will be developed, and there are likely to be alternatives to the media described above. Those responsible for future information management should be encouraged to consider the full range of classical and novel media and recording systems in order that access to key information be maintained.

(q) With respect to electronic media the recommendations of the storage media or system manufacturer should be used for specific maintenance instructions; however, the following minimum standards should be maintained for electronic records storage:

(i) In no case should electronic records storage be conducted outside a properly designed, maintained and controlled facility.

(ii) In no case should work, electronic devices or demagnetizing equipment be allowed in the storage facility.

(iii) All media and containers should be examined on entry into or removal from the storage facility to prevent inadvertent corruption or contamination of archived records/media. This includes scanning for viruses and other malicious software using appropriate virus protection software.

(iv) Electronic records storage media should be shielded from electronic signals.

(v) Original records and record media should be maintained off-line. Copies of electronic records may be maintained on-line for use if they are either:

—Properly secured, maintained and verified to ensure their replication of the original record, or

—Used for information only purposes.

(vi) Only write-once read-many (WORM) media should be considered for the original copy of archived records.

(vii) Where it is not practicable to provide suitable storage conditions, consideration should be given to the provision of a duplicate set of records stored in a separate facility. In that case, the location and construction features of both facilities should be such that the probability of simultaneous destruction, loss or deterioration of records is sufficiently low.

(viii) In no case should the original records/media be used for work purposes or maintained on-line.

(ix) Where original record data (i.e. database data and email systems) are maintained on-line for business purposes, the record data should be copied to separate media and maintained off-line for archival purposes.

(x) A statistical sample of media records should be read each year to identify any loss of data and to discover and correct the causes of data loss. If errors are discovered, other media that might have been affected by the same cause (i.e. poor quality media, high usage, poor environment or improper handling) should be read and corrected as appropriate.

(xi) Data on flawed media should be transferred to new media and quality verification conducted and documented.

Appendix III

LONG TERM PRESERVATION RESEARCH

Research and assessment of long term preservation of records and knowledge will need to continue over time and will involve many disciplines.

Research into the long term preservation of records is likely to involve experts from a wide range of disciplines, such as archivists, historians, material scientists, data storage experts (analogue, electronic and digital systems) and sociologists. There will be an ongoing need for such research as technologies change and civilizations evolve.

Examples of research needs in this area include [2]:

(a) Basic research into the validity and maintenance of visual signs.
(b) Identification of media suitable for the long term preservation of records.
(c) Improvement to the procedures for ensuring that records are migrated without data losses as media change over time.
(d) Improvement of methods that ensure the long term retrievability and accessibility of records and information.
(e) Research into the coding of information so that it might be readable by future generations.
(f) Research into the basic mechanisms by which historical records have been successfully, albeit often unintentionally, preserved over long periods of time (e.g. natural and anthropogenic analogues, such as old manuscripts).
(g) Historical research into the tradition of written records (e.g. ancient Chinese texts, Egyptian texts, the Bible and the Koran) as well as the properties and procedures that kept them understandable.
(h) Further research into the long term stability of materials (e.g. paper, ink, optical storage devices and materials, as well as novel materials) and their interaction with the storage environment.
(i) Identification of ways that will probably ensure that records are safely kept and secured in the long term.
(j) Development of risk assessment methods for various types of records management strategies, balancing the investment into the management of the records with the risk of loosing these records. This research will also aid in identification of the weaknesses of certain designs and practices, leading eventually to improvement and mitigation.
(k) Further research and development into sound methods for records indexing.

(l) Further research and development into sound methods for classification of records.
(m) Develop internationally agreed signatures and symbols for maps indicating use restrictions.

Appendix IV

SOFTWARE SOLUTIONS TO SUPPORT LONG TERM DIGITAL PRESERVATION

IV.1. INTRODUCTION

In order for different organizations to share digital preservation experiences and learn from each other, it is essential that each solution can be compared. However, digital archiving is a relatively young discipline and, as such, standards are in their infancy. Nonetheless, ISO are encouraging the development of good practices and have endorsed the reference model of the US National Aeronautics and Space Administration (NASA) for an Open Archival Information System (OAIS) [60, 61].

OAIS is an ISO reference model [62] for archival systems intended for the long term preservation of information, with a particular focus on digital records. While the reference model does not describe how to build an archive, it provides a common view of the concepts, terminology and functions required of a digital preservation system. This reference model represents a considerable body of work and expertise, and should be the starting point for any digital preservation system.

However, as with any reference model or framework, by itself it does not guarantee a robust solution. In 2003, the Research Libraries Group (RLG) combined with the Online Computer Library Center (OCLC) to create the guide 'Trusted Digital Repositories: Attributes and Responsibilities' [63]. In 2005, RLG and the US National Archives and Records Administration (NARA) then took this further by creating the 'RLG–NARA Audit Checklist for Certifying Trusted Digital Repositories' [64]. Taken together, these will help ensure that the efficacy of any archival system can be assessed.

The problems of archiving OAIS are split, as shown in Fig. 11, into six functional entities:

(1) *Ingestion* — This covers the issue of getting records into an archive, including the capture of appropriate metadata to allow them to be found, extracted and meaningfully used many years into the future.
(2) *Data management* — This covers the controlled editing of data input into the system.
(3) *Storage* — This covers the issue of physical storage of records in an archive, including the creation of an appropriate backup policy and regular media migration.

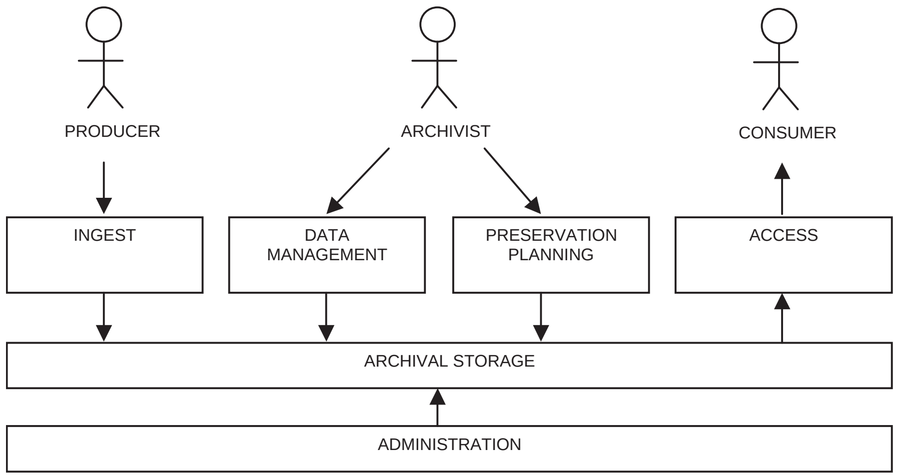

FIG. 11. Schematic view of the OAIS model.

(4) *Access* — This covers two related aspects, finding records within the archive and disseminating them to consumers. This includes ensuring that the appropriate information is only disclosed to appropriate users of the system.

(5) *Preservation planning* — This involves ensuring that the contents of an archive remain more than just a meaningless bitstream.

(6) *Administration* — This covers the running of the system itself including its maintenance.

The preservation planning aspect of the OAIS road map is worthy of detailed inspection as this covers the issue of maintaining access to digital records over an extended period of time. There are effectively three approaches to implementation of preservation planning.

IV.2. MUSEUMS

One possibility would be to maintain the old hardware and software used to create the data and records initially. However, this is not very practical. Such a solution would require the maintenance of every combination of hardware and software required. The hardware would become increasingly expensive to maintain and would eventually become irreparable. This is really only an interim measure.

IV.3. MIGRATION

In this technique, a copy of the original is transformed into another, more modern, format (Fig. 12) that can be read using newer application software (potentially running on updated hardware with a newer operating system). For instance, scientific data in a binary format may be transformed into a document conforming to an XML schema, which (as it is self-describing and based on very simple low level technology, i.e. it is fundamentally just a simple text file) is less vulnerable to obsolescence. In more complex cases, it may be necessary to perform a series of transformations over the lifetime of the data, either because of a change in the available application software or because a better transformation engine becomes available. In such cases, it is normally preferable to return to the original file and transform this into the new format, rather than transform it from the previous migration (as this will potentially already have lost some of the information in the original).

To make this approach easier, it would be best to restrict the number of formats by moving towards standardization. One example where standardization has worked is in image formats where specifications, such as TIFF, have been almost universally adopted by software manufacturers, as they have realized that there is a larger overall market if images can be readily exchanged. In some cases, such as in colour specification, manufacturers have actively collaborated (forming the International Colour Consortium) to ensure standardization has been implemented. While standardization has many

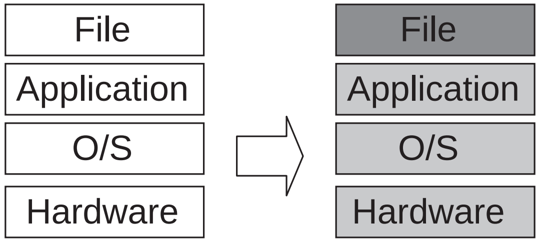

FIG. 12. Migration involves accepting that natural changes occur to hardware, operating systems (O/S) and application software (light grey changes), and therefore the original file is deliberately transformed (dark grey change) in order to allow a record to remain readable.

attractions, the commercial companies that create the majority of application software in use at present are unlikely to follow this route unless there is a competitive advantage to be gained. In addition, it is worth remembering that it is not always trivial to translate records from their current formats into a standard format, as such a transformation may require archivists to make assumptions about the intentions of the original author(s).

Migration need not occur only for preservation purposes, it could also occur to allow easier presentation. For instance, if a digital record consists of Microsoft Word files, a consumer could choose to download the records to their local PC and read them using a locally installed copy of the software. An alternative would be to create an HTML rendition of this file and display this to the consumer instead. Third party products exist that will perform such migrations for a number of formats with a reasonable degree of integrity.

The fact that migration involves a transformation that may result in loss means that it is necessary to understand and categorize this loss so that different transformation software can be assessed and compared. The attributes that need to be considered can be divided into five categories:

(1) *Context* — This is set by metadata and is thus unaffected by migration (although the migration process should itself be documented).

(2) *Content* — A good transformation should preserve all the content of the original. However, sometimes the new format will not allow information to be kept in exactly the same form.

(3) *Structure* — It is important to remember that, if an accession undergoes migration, for preservation or presentation purposes, the logical (technology independent) structure will be preserved, but the physical (technology dependent) structure may be altered, as not all migrations will lead to an exact one-to-one file correspondence. This means that migration is potentially a complex process, and as such could be prone to human error (e.g. marking a file incorrectly as having been superseded by a newer version).

(4) *Appearance* — It is quite difficult to preserve the look and feel of the original when performing a migration. For most purposes, this may not be too important but there is not always a clear-cut distinction between appearance and content. For instance, if an author uses bold or italics at some point in a document, it is probably an emphasis and can thus be interpreted as being part of the content of that document.

(5) *Behaviour* — One of the advantages of digital records is that it is possible to manipulate the information within them. For example, database records can be queried to provide new views of the information contained within them or a model can be rerun using different initial parameters.

This aspect of a digital record relies on the programming logic embodied in the application software and is thus difficult to preserve by migration.

One of the key aspects of preservation planning is ensuring that the strategy for data types is reviewed regularly (e.g. a strategy for a given data type that is relying on the use of a given piece of application software will need to be reviewed if support for that application ceases). This means that there is a requirement to maintain a repository of information about each file format stored in the archive, to assist archivists in determining the best preservation strategy for it (e.g. to plan when each format will need to be migrated). This strategy may evolve with time as better technologies become available. With assistance from Tessella, the UK National Archives has created such a library (called PRONOM), designed to share information with other archiving organizations and to allow anyone to submit information on new formats [65].

The ideal scenario for a large archive would be to automate the migration process. The process would then work something like this:

(a) An archivist updates the file format repository to state that migration of format XYZ is now required and that the approved policy is to migrate to format ABC using a specified piece of software.
(b) The archive automatically detects the update and calculates that this will require *x* hours of processing time.
(c) The archive schedules this processing to occur at relatively quiet periods (e.g. over the next few nights or over a weekend).
(d) The migration takes place automatically. Humans need only be involved to provide a quality check (although even this process could be assisted by appropriate software tools).

IV.4. EMULATION

An alternative to migration is to use emulation. There are variations of this technique, but the most promising would seem to be hardware emulation where the original file, application software and operating system are retained but, since it is accepted that hardware will become obsolete over time, the original hardware is emulated in software on new hardware (Fig. 13).

This technique potentially has an advantage over migration in that it should allow the look, feel and behaviour of the original application to remain intact (whereas these are potentially lost in migration). This will be especially helpful for records with a high degree of behavioral content (e.g. virtual reality

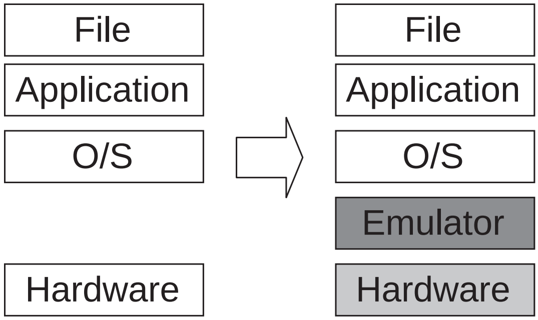

FIG. 13. Hardware emulation involves accepting that natural changes occur to hardware but with no changes to the original file, application software or operating system (O/S). Enabling the software to continue to run requires the creation of an emulator (dark gray change) to emulate the original hardware on the new hardware.

models). In addition, for a given piece of hardware, such an emulator can be written once and reused by many organizations (although an emulator may need to be rewritten when the hardware changes again). However, such generic emulators do not yet exist; thus, the concept cannot yet be seen to be a proven universal approach. The approach also means that licensed copies of the original application software (in fact a record may rely on many applications to operate as originally intended) and the original operating system must be retained, including the relevant bug resolutions and service releases. It also means that the effort required to access an old record could be considerable, since the original application software and operating system must be installed together with the emulator before the record can be meaningfully interpreted.

There are two emulation methods:

(1) *Operating system emulation* — In this case, we retain the original file and application software and accept 'natural' evolution of both the operating system and hardware.

(2) *Application software emulation* — In this case, we retain the original file and accept 'natural' evolution of the application software, operating system and hardware.

Neither of these seems as feasible as hardware emulation. For example, see the summary of the result of the Dutch Government's Digital Preservation Testbed project for more details:

www.digitaleduurzaamheid.nl/bibliotheek/docs/white_paper_emulatie_EN.pdf

This project also involved exploring strategies for long term digital preservation of the four most common types of digital record, with various case studies being made:

(1) Email preservation [66];
(2) Text preservation [67];
(3) Spreadsheet preservation [68];
(e) Database preservation [69].

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Annex I

EXAMPLES OF NATIONAL EXPERIENCE

The examples provided in these annexes range from national policies and programmes to the detailed organization of decommissioning for both small and large facilities. Both approaches are useful to provide practical guidance on how information to support decommissioning projects is managed in various countries.

The examples given are not necessarily best practices; rather, they reflect a wide variety of national legislation and policies, social and economic conditions, nuclear programmes and traditions. Although the information presented is not intended to be exhaustive, the reader is encouraged to evaluate the applicability of these schemes to a specific decommissioning project.[1]

[1] National annexes reflect the experience and views of their contributors and, although generally consistent with the guidance given in the main text, are not intended for specific guidance.

Annex I–1

THE NETHERLANDS: RECORD KEEPING OF THE DODEWAARD NUCLEAR POWER STATION

I–1.1. INTRODUCTION

The Dodewaard nuclear power station (Gemeenschappelijke Kernenergiecentrale Nederland (GKN) or KernenergieCentrale Dodewaard (KCD)) was built in the period from 1965 until 1968. It started commercial operation on 26 March 1969 and was shut down after exactly 28 years of successful operation. The objective of the plant was to acquire experience in operating an NPP in order to generate electricity and to create research opportunities in the field of nuclear energy. The KCD plant was a small demonstration power station and was never intended to generate electricity on a commercial basis. In 1996, when it became clear after a parliamentary discussion that construction of new NPPs in the Netherlands was not feasible for the foreseeable future, the Dutch Electricity Generating Board (SEP N.V.) announced the shutdown of the station. It was decided to put the plant into a safe enclosure (SE).

The Preparation for Safe Enclosure (PSE) project started in March 1997, with the transport of spent fuel to a reprocessing company.

After this, the plant was transferred into an SE with all non-radioactive contaminated buildings removed. The plant reached SE status on 1 July 2005. The SE is of an active type, with a limited staff on-site and a forced ventilation system. It is believed that the SE will run for 40 years. After this period, decommissioning to greenfield conditions will be performed.

I–1.2. ARCHIVES

The need for creation of a new central archive for records relevant to decommissioning was realized by GKN.

Therefore, three basic archives were created:

(1) An historic archive, containing relevant technical information about the plant, its development and history. This also includes, besides the technical documents on plant equipment, drawings, photographs, information on fuel, etc.

(2) Dose rate and a contamination map, the Dodewaard Inventory System (DIS).

(3) The SE operational archive. This contains all the information necessary for operating the SE and relevant records created during SE operations.

The general comprehensive scheme is shown in Fig. I–1.1.

I–1.2.1. Historic archives

Immediately after the announced shutdown, a project was started to create an historic archive (Annex 1.J of Ref. [1]). This project was started after the State archive of the province in which GKN is located (Gelderland) requested GKN to transfer relevant records to the official Governmental archives. This was requested with a view to securing the records for future generations.

This archive was named Rijksarchief Gelderland (RAG) but changed its name to the Gelders Archive (GA) in 2004. The GA has secured archives of numerous companies and families in order to provide historians with an opportunity to carry out research on them.

In the Netherlands, all 12 provinces have their own archive. Together with the national archives in The Hague, they form the State Archive Service, which comes under the management of the Ministry of Education, Culture, and Science. These archives have been in operation for centuries and will operate indefinitely. Documentation once brought into these archives stays there indefinitely.

It was realized by GKN that this State archive could also be a safe location in which to save relevant records for decommissioning, as the information carriers are conditioned before they are allowed to enter the archives. Atmospheric conditions are maintained in the archives.

The historic archives consist of three parts.

(1) The first part covers the period 1965–2000. This part has been completely catalogued by the personnel of the GA. An overview of documents included in this part is available in a booklet and will soon be available on the Internet. The documents themselves are not available on the Internet but can be visited by making an appointment with the GA in the town of Arnhem. Parts of these documents will be made public after 25 years as they contain commercial information on fuel. All other documents are in principle open to the public, but permission must be given by both the GA and the GKN before any member of the public can view the archives (Freedom of Information Act).
(2) The second part covers the documentation from 2001 until the start of SE operations on 1 July 2006. All documents are preselected and transferred

from the NPP to the GA. The same restrictions for use will apply as for the first part.

(3) The third part consists of about 30 000 photographs and about ten official documentaries on film. The Dodewaard NPP had a policy to have all equipment photographed in order to be able to discuss equipment issues in meeting rooms rather than in the field. Some of those photographs were made during special occasions such as official events, demonstrations and special tests. All these photographs have been categorized, and about 5000 were selected for permanent storage in the directly accessible cupboards of the GA. They will also be scanned and made available on the Internet. There will be no restrictions on the use of these photographs by members of the public, as the photographs are pre-screened by staff from both the GA and GKN. An overview of the photographs and the photographs themselves became available on the Internet recently. The documentaries can be viewed in the GA reading room.

All documents consist of paper, drawings on tracing paper, microfilm and film. All documents are cleaned of staples, paper clips, plastics, etc. After this the material is treated by X rays to kill microbes. Final storage is in conditioned warehouses, controlled by the GA.

I–1.2.2. Dose rate and contamination map

Directly after shutdown a group of health physicists, physicians and former operators started to collect information on dose rates and surface contamination. All of this information was brought into a database. In this database, it is possible to see the radioactive components of the plant, their location, the contamination, the dose rate at the outside, the mass, the material and the nuclide vector. Furthermore, specific information for a component can be added. In the database, the results of special measurements are reported, such as contamination outside the buildings and the results of measurements on the concrete biological shield. The database is created in such a way that several types of report can be generated.

The database is kept by an outside company, which specializes in setting up and maintaining these kinds of record. GKN arranged a contract with this company to prepare an annual report on the total radioactivity in the plant and its components. The contract includes maintenance of the software used for the database and a change of software and hardware types when necessary. In this way, it is assured that the information will be available for the SE period of operation and the final dismantling. A periodic backup system for the database is in place, in the outside company’s offices. By producing an annual report on the actual inventory, it is assured that the data are up to date, as this report is checked by station personnel.

New information can be added to the database by selected staff members of GKN and the outside company. The information is continuously available on an Internet page for individuals who are granted access to these pages. A hard copy version of the results and input data to the database is kept at the station.

I–1.2.3. Safe enclosure operational archive

The SE operational archive has inputs from three sources:

(1) Documents prepared during PSE;
(2) Documents about new equipment;
(3) Records created during operation of the SE.

The documents prepared during PSE consist of drawings and records providing information about how the plant was taken out of service. This information is not necessary for final dismantling but can be of help. The relevant information on this subject is transferred into DIS.

The technical information package (TIP) is important. This consists of the background information used for the preparation of the safety report (VR) for the SE period.

The documents about the new equipment that has been installed were obtained from the company that transferred the NPP into the SE. This information is used on a daily basis and provides information about all the components that are still in operation.

During SE operation, records will be created. The raw data are stored on an external server with a backup facility, while the official reports such as the 'Quarterly Report to the Regulator Body' are printed and stored.

The operational archive is partly stored on-site as hard copy and partly stored at an off-site office as hard copy. The basic documents used for creating the VR are stored on DVDs and are located on-site and in the off-site office.

Part of the information generated during the operation of the SE will be added to DIS. After completing the decommissioning of the plant, some parts of the SE archives will be transferred to the GA, and treated and stored in the same way as the historic archive is treated.

I–1.3. CONCLUSIONS

By storing its most valuable archives at a Governmental organization, the availability of these archives is secured in the future.

Relevant information on radioactivity and components in the plant is stored on a database that is maintained by an outside company.

Day by day records are kept on-site and in a separate office in both hard copy and DVD formats.

In this way, GKN will be able to start the final dismantling of the plant, with sufficient information available and retrievable. Figure I–1.1 provides a graphical description of the Dodewaard record management scheme.

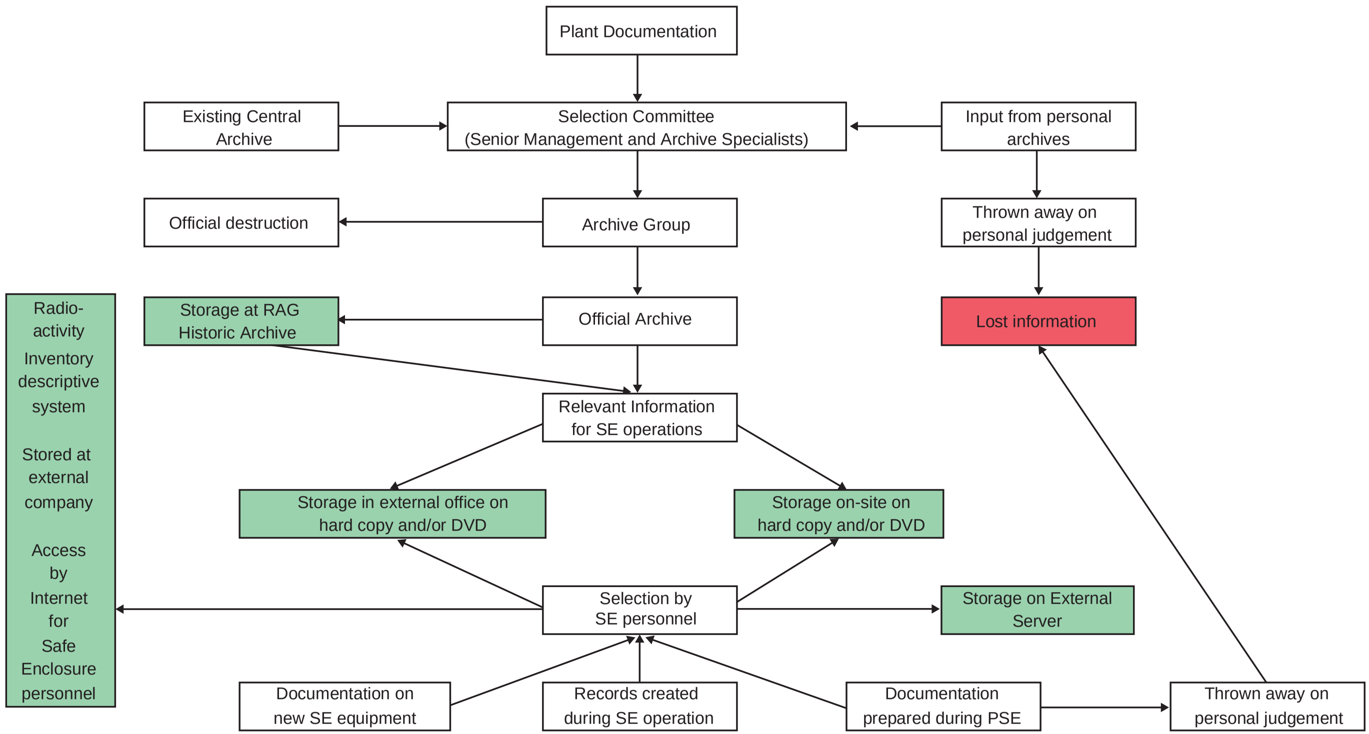

FIG. I–1.1. Overview of archives and record keeping of GKN Dodewaard, the Netherlands. Note that the green boxes highlight where the records are stored, while the red box highlights what must be avoided.

Annex I–2

SWEDEN: THE SWEDISH NUCLEAR ARCHIVE REGULATIONS AND PROJECTS RELATED TO CORPORATE MEMORY

I–2.1. INTRODUCTION

The Swedish radiation protection authority regulations on Filing at Nuclear Plants, SSI FS 1997:1, apply to filing of documentation that has been drawn up or received in connection with practices at nuclear plants.

The regulations set out:

— The minimum level of documentation;
— Archiving requirements;
— Availability periods;
— Choice of data carrier;
— Timely transfer to new media;
— Requirements regarding safe keeping of documents.

The regulations require that, if the nuclear activity ceases, the archives must be transferred to the Swedish national archives.

Examples of the availability periods required for records and environmental specimens are as follows:

(a) Operations related measurements — 25 years;
(b) Emergency response plan — 50 years;
(c) Report of an unusual event — 50 years;
(d) Documents relating to final disposal — long term;
(e) Environmental specimens — 10 years;
(f) Records of measurements on specimens — long term.

I–2.2. ACTIVITIES TO SUPPORT THE MEMORY AND DOCUMENTATION OF THE MAIN LABORATORY AT STUDSVIK FOR HANDLING RADIOACTIVE SUBSTANCES

In a report from 2001, Nordlinder and Hallberg [I–2.1] gave, on the basis of older printed material and interviews with 14 experts (some of whom were retired), a description of activities involving the waste streams to the Aktiva centrallaboratoriet (ACL), the main laboratory at Studsvik for handling radioactive substances. The unit started in 1963 and operations ceased in 1997. The report describes the activities carried out in the laboratory over different periods, and constitutes a reference in connection with the planning of decommissioning work.

I–2.2.1. The ACL facility

The ACL facility was built around 1960 as the central national nuclear laboratory. It was used for different purposes, such as research on plutonium and enriched fuels, testing of materials in hot cells, production of radiation sources, testing of iodine filters, decontamination of plutonium contaminated equipment, and different kinds of waste treatment (e.g. development of methods for pyrolysis of ion exchangers and supercompaction of waste drums).

The facility is situated at Studsvik, about 100 km south of Stockholm. It consists of two buildings – the laboratory itself, and a ventilation and filter building (the Active Central Filter (ACF) building). The ACL facility consists of a three storey building with outer dimensions of 65 m × 72 m. It contains more than 50 rooms, which have been used for laboratories, testing of equipment, decontamination, storage of material and waste, etc. There are also a number of rooms for service systems (e.g. for ventilation equipment), corridors, culverts, etc. The floor surface is approximately 14 000 m^2 (including ACF).

I–2.2.2. The report

Nordlinder and Hallberg's report [I–2.1] testifies to the great diversity of activities carried out in the 1960s and 1970s, covering 21 different headings. The room location for the activities is given for all activities. A few examples are mentioned below.

From 1964 to the end of the 1970s, work on plutonium chemistry was mainly carried out using gloveboxes. About five rooms were used for production of fuel pellets, and investigation using autoradiography, investigations of metallographic size and thermal properties. The first step of dismantling and decontaminating gloveboxes was taken in the late 1970s.

The radiation sources ^{90}Sr and ^{222}Rn were produced for a few years around 1980. The medical activities also included radiotherapy of tumours onsite during the 1960s.

Reactor chemistry with ^{51}Cr, ^{59}Fe and ^{60}Co was carried out during the 1980s, and experiments into the behaviour of iodine in fuel were done from 1965 until 1975.

The facility was also used for preliminary waste storage for a number of waste types, described in the report.

I–2.2.3. Documentation

A table is produced to give room-by-room activities through the different time periods the facility was used. Six different interview protocols are included, in addition to references to existing reports in the Studsvik archive.

I–2.3. THE SWEDISH NUCLEAR FUEL AND WASTE MANAGEMENT COMPANY

The Swedish Nuclear Fuel and Waste Management Company (SKB) carried out a project related to their corporate memory starting in 2000, by interviewing a large number of key persons, around 50, both inside and outside the organization. The project was lead by P.O. Lindberg of SKB.

The project was carried out using taped interviews and included senior experts who gave personal accounts of earlier decisions within the organization regarding technical and policy issues.

Key figures outside the organization were also interviewed, such as C. Odhnoff, the first person to chair the Swedish National Council for Nuclear Waste (KASAM), established in 1985 as an independent advisory committee attached to the Ministry of the Environment. The interviewees also include a person who campaigned against SKB during the early phase of the feasibility studies carried out in northern Sweden.

Although the first part of the task has been carried out, the project will continue to be updated by adding a few interviews per annum [I–2.2].

REFERENCES TO ANNEX I–2

[I–2.1] NORDLINGER, S., HALLBERG, B., Radiologisk verksamhet i ACL, Rep. ES-01/42, ACL, Studsvik (2001) (in Swedish).

[I–2.2] NÄRINGSLIVETS ARKIVRÅD website (in Swedish), www.nla.nu

Annex I–3

CANADA: LIABILITY INFORMATION MANAGEMENT AT AECL

I–3.1. INTRODUCTION

Atomic Energy of Canada Limited (AECL) is responsible for a number of licensed nuclear sites in Canada. Three prototype reactors: the Nuclear Power Demonstration Reactor (NPD), Douglas Point (DP) and Gentilly-1 (G1) are being decommissioned in phases. The Whiteshell Laboratories (WL) research site is currently being completely decommissioned. The Chalk River Laboratories (CRL) site, which is AECL's oldest, largest and most operationally diverse site, has operated since the 1940s, and is expected to continue to operate for the indefinite future. As a result, decommissioning activities to remove redundant facilities and buildings, creating space for construction of new facilities, are more complex, as they are being carried out at an operating site.

The involvement of AECL in decommissioning activities at these sites started in the 1980s, and since that time the decommissioning programme has continued to grow as sites and facilities are declared redundant, shut down and decommissioned. Significant effort has been put into the preliminary and detailed planning of the decommissioning for both individual facilities and the WL and CRL sites as a whole. The decommissioning programme involves planning, assessing, monitoring and executing projects to decommission the buildings and facilities. The programme currently encompasses a diverse variety of facilities, including prototype and research reactors, fuel processing facilities, research laboratories, waste processing facilities, buildings, structures, land and waste storage areas. Many of these buildings and structures have been used for a variety of purposes as research and business requirements have evolved over their lives.

I–3.2. BACKGROUND

As AECL's decommissioning experience has grown, so too has its understanding of the value and importance of a comprehensive records and information base, about the full life cycle of the site/facility [I–3.1].

Without a comprehensive records and information base, the decommissioning programme would face greater risks, higher costs and longer schedules. Examples of the issues that could arise are the following:

(a) Additional cost would be incurred in searching for and gathering information from scattered sources.
(b) Additional characterization activities might be required to gain knowledge about the less well understood facility and its associated risks.
(c) Projects could take longer if a conservative approach to decommissioning activities is needed because of unknown factors. An example would be the requirement for more extensive radiological surveys if information and records, giving details of which radioisotopes were used and where, do not exist or are not clear.
(d) Additional work may be required to satisfy the regulator that the risks are known. For example: site baseline information is critical when demonstrating that the end state of a return to greenfield (original) condition has been achieved.
(e) Projects may face delays to their schedules if unknowns are encountered or if incidents occur. A prime example would be the possibility of a work stoppage if an accident occurs.
(f) It may be necessary to reconstruct information (e.g. drawings, safety cases, operating environment, evaluations and surveys or equipment specifications) before work can be identified, planned or executed. There may be an increased risk of incidents occurring during the execution of decommissioning work.
(g) Additional time may be required to determine, validate and confirm information about the facilities and old practices, particularly if few records exist to help substantiate the information, or where available historical practices and process knowledge is sketchy because operational staff/retirees are no longer available to assist.

A large volume of records must be managed over the life cycle of a site or a facility, and for a minimum of ten years after final decommissioning has been completed [I–3.2, I–3.3] in order to meet regulatory and operational requirements, particularly for licence-listed nuclear facilities. The overall time frame can be very long for a facility, which may be operated for over 50 years, and then maintained in a storage-with-surveillance state for over 50 years before final decommissioning even begins. Site records may even be required for an even longer period of time as they may be required during an extended institutional control period after the site has been decommissioned. Site and facility records may include: drawings, logs, memos, reports, photographs, maps, notes and forms, in various formats: electronic (file formats and storage medium) and hard copy (paper) and film. These collections continue to grow over the entire facility life cycle, from the initial concept until after the final decommissioning end state has been achieved:

(a) Develop concept and site;
(b) Design, construct and commission;
(c) Operate and maintain;
(d) Shut down;
(e) Decommission.

Since a number of AECL's sites and facilities have already operated for nearly 50 years, a very large volume of historical information has been generated and must continue to be managed, organized, assessed, protected and made available to staff. Most of these historical records are available only in hard copy form, and are therefore not easily accessible for search and access. Where historical records are incomplete, records of historical operations may need to be captured or generated using alternative methods such as retiree interviews.

The long term management of this information can be quite daunting, particularly for reactor facilities whose operational phase alone may be 50 years, followed by another 50 years or more of storage with surveillance, and then final decommissioning. The management of this information for a site may even be more challenging, since the life cycle of the records for a large portion of the collection is then even longer than that of the facilities themselves [I–3.4].

To tackle this task, the liability management unit (LMU), which manages AECL's decommissioning programme, has defined two key goals for decommissioning records and information management [I–3.5]:

(1) *Records management* (to manage actual records) — To manage, organize and protect the records base required for decommissioning that exists throughout the site's and/or the facility's life cycle and until at least ten years after decommissioning [I–3.2]. The records base continues to grow as new records are generated throughout the decommissioning phases.
(2) *Information management*: (to manage knowledge derived from the records) — To create a decision support information base from the records, which have been identified as important to decommissioning, and to make this subset the 'vital few'. This information will be electronically available to staff in order to support their decommissioning activities. The information base will continue to grow over time as new information is identified as important, particularly as the decommissioning work moves from strategic and preliminary planning to detailed planning, storage and surveillance, and project execution.

I–3.3. RECORDS AND INFORMATION MANAGEMENT STRATEGY

To achieve the records and information management goals in a cost effective manner, the LMU has embarked on a strategy to manage and improve information handling by establishing, populating and managing a decommissioning records and information framework.

The liability information management (LIM) strategy has been to systematically improve the management, protection and access to the required records information. The key stages of the strategy are illustrated in Fig. I–3.1.

I–3.3.1. Establishing a records and information framework

The approach taken by the LIM was to establish the decommissioning records and information framework by identifying and assessing:

(a) WHAT records/information would be needed for decommissioning;
(b) WHICH facilities were to be decommissioned;
(c) WHEN records/information would be required;
(d) WHERE records/information sources existed of relevant facility records/information;
(e) HOW records/information were to be managed (practices, tools and facilities).

This information was then categorized and grouped by type to create a decommissioning asset information model, which identifies the information required for each of the facilities (including sites, facilities, buildings, structures, waste management areas and affected lands). The key types of information categorized were:

(a) *General background*: Site, design concepts and business;
(b) *Physical characteristics and configuration*: Maps, drawings, modifications, materials, equipment, photographs, services and surroundings;
(c) *Operations and maintenance*: Licence, status, logs, procedures, operating plans and records, operating instructions, usage/processes, flow sheets, maintenance plans and records, inspection records, purchase orders and parts;
(d) *Regulatory and legal*: Nuclear, environmental, industrial — licences, regulations, guidelines, correspondence, permits and authorizations;
(e) *Health, safety and environmental*: Unusual/unplanned events, hazards/risks (radiological, chemical and industrial), safety assessments, radiological surveys, logs, annual reports and minutes of safety meetings;

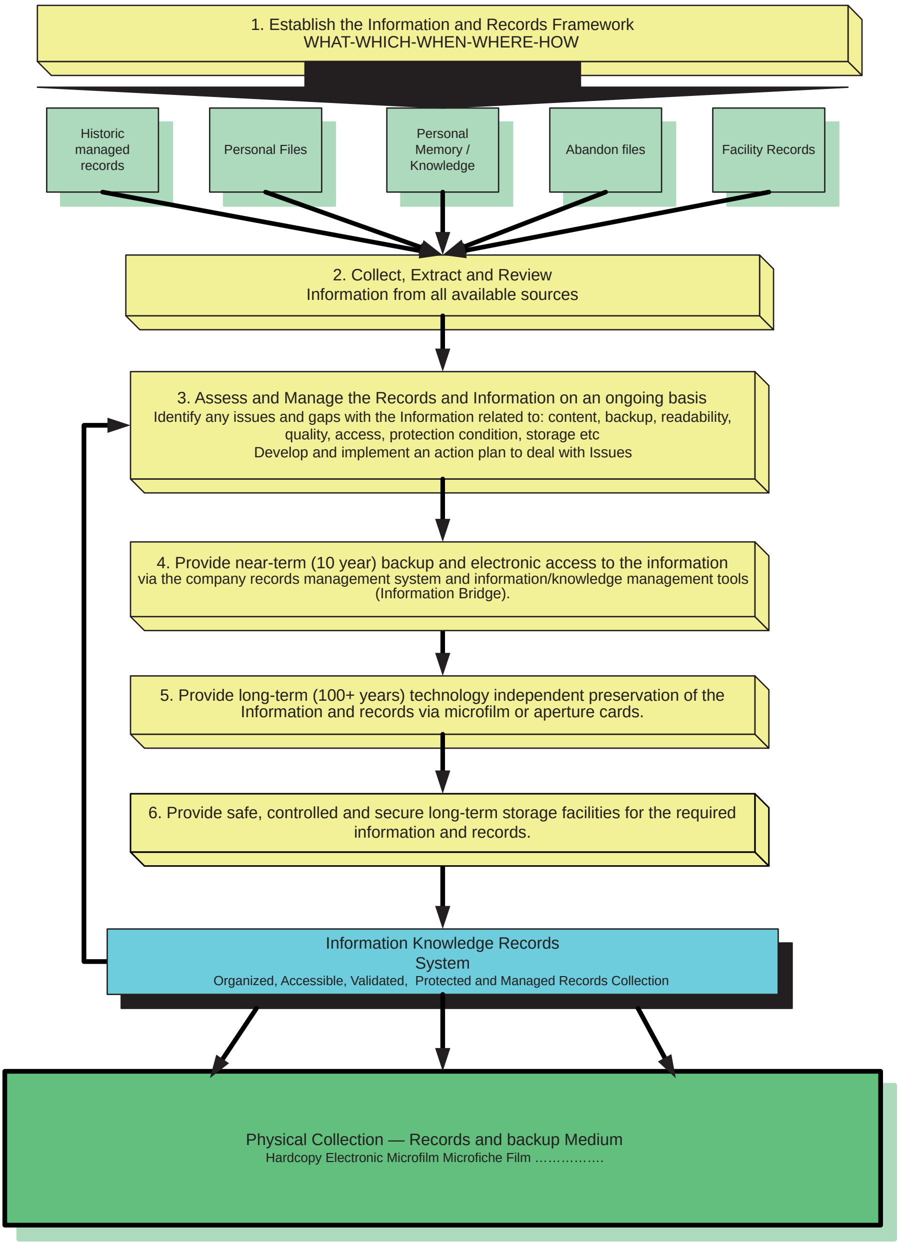

FIG. I–3.1. Process to populate, maintain and preserve records and information.

(f) *Waste generation*: Waste generated records, characteristics and volume during operations through decommissioning;
(g) *Decommissioning*: Strategies, preliminary and detailed decommissioning plans, environmental assessments, analysis reports, characterizations, storage-with-surveillance plans, project plans and end state reports.

I–3.3.2. Identification, gathering, assessment, consolidation and organization of hard copy, electronic records and other information

Once the decommissioning records and information framework was established, a series of activities was systematically carried out for each facility within the decommissioning programme. This framework must continue to be operated and enhanced or improved for each facility as long as the records are required.

I–3.3.3. Assessment and management of records and information

The records and information base that has been established for each facility must be managed, maintained and updated on an ongoing basis. New records continue to be generated and added to the records and information base for the remainder of the life of the facility, particularly as the various decommissioning activities are carried out. Additional information may also be found or identified as being important and will need to be added.

To ensure that decommissioning staff members are aware of new information and records being entered into the information base, on an ongoing basis, a report is generated from the records and information base and distributed to staff, identifying all the information that has been entered recently.

As facilities are scheduled for decommissioning, the records for that facility need to be reviewed, assessed and prepared for transfer, and the record retention requirements reassessed to determine if and when the records will no longer be required. As the facility is shut down, the record transfer plans will be implemented.

The facility records and information bases need to be reassessed on an ongoing basis, to ensure that their content is up to date and relevant to the current and future needs of the decommissioning group. The physical characteristics of the original records and backup media are reviewed to ensure that the records are not deteriorating and are still readable and useable. Similarly, the electronic records and the RMSs must be assessed and scheduled for migration and updated respectively every five to ten years (Note that these migration activities must include extensive QA validation and verification, to ensure the record integrity is maintained). In addition, the records management practices, system, tools and records storage facilities will also be reassessed to ensure that they are kept up to date with new procedures, rules and regulations, technologies, modernization and cost effectiveness.

I–3.3.4. Provision of near term backup and electronic access

Where records are identified as required for future decommissioning or liability management activities, the records will be digitized and stored in an RMS to provide near term backup of the records and electronic access to the records. The electronic records will also be indexed/linked in the liability management information bridge, where the additional metadata will be captured about the records to provide enhanced information and knowledge management search and retrieval capabilities.

I–3.3.5. Provision of long term preservation of records

Decommissioning projects are required to keep the records until at least ten years after the final end state has been achieved to meet regulatory requirements, and some of the decommissioning records may be required for even longer periods of time to address liability, record national history and inform future generations. As a result, a significant portion of the site and facility records may have a useful life cycle of more than 100 years. The decommissioning projects dealing with the transfer and management of historic facility records that are several decades old (and that will need to be managed for several more decades) must also continually collect and manage new records, which are generated as decommissioning activities progress throughout the term of the project.

To accomplish this, a long term (100+ years) technology independent preservation strategy is being implemented for the records that are essential. This strategy builds the near term backup and storage framework of electronic records management and using electronic micro-imaging generates microfilm or aperture cards. Index information about the microfilm is then stored back into the electronic RMS.

I–3.3.6. Provision of safe, controlled and secure long term storage facilities

The hard copy and film records must be stored within records management facilities, which are designed to store records for 100 years or more. Typically these are defined as ‘records preservation facilities’ and have specified environmental, access and security controls requirements. Similarly, the electronic records must be managed to ensure their longevity and integrity. The ERMS must be centrally managed with record tracking audit trails and access control. The ERMS hardware must be located on central servers that have strict access, security and environmental controls. Disaster recovery plans also need to be established and tested, for both the hard copy and electronic records together with the related storage facilities, as well as software and hardware systems.

I–3.4. CONCLUSIONS

It is critical for decommissioning projects to have their records and information bases continually reviewed, assessed, migrated and updated, to ensure that the collection will be preserved on stable media to meet ongoing and changing requirements, technologies, formats and tools. Ongoing challenges, such as conflicting retention requirements, changes in record ownership, technological changes, migrations and advances, record destruction criteria, long term storage formats and long term records storage facilities, must be managed and addressed.

The creation and implementation of the LIM programme has helped to ensure that the value of the records and information base required for both safe and cost effective liability management and decommissioning of AECL's sites and facilities is recognized, and that the base is managed effectively.

The programme will continue to be refined and enhanced as AECL gains experience and knowledge with the full life cycle management of records and information with very long term retention periods.

REFERENCES TO ANNEX I–3

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[I–3.2] GOVERNMENT OF CANADA, Nuclear Safety and Control Act: Class I Nuclear Facilities Regulations, SOR/2000-204, Government of Canada, Ottawa (2000).

[I–3.3] INTERNATIONAL ATOMIC ENERGY AGENCY, Quality Assurance for Safety in Nuclear Power Plants and Other Nuclear Installations, Code and Safety Guides Q1–Q14, Safety Series No. 50-C/SG-Q, IAEA, Vienna (2001).

[I–3.4] LIBRARY AND ARCHIVES CANADA, Records and Information Life Cycle Management (2004),
http://www.collectionscanada.ca/information-management/002/007002-2012-e.html
[I–3.5] CANADIAN NUCLEAR SOCIETY, "Decommissioning information management in decommissioning planning and operations at AECL", in Waste Management, Decommissioning and Environmental Restoration for Canada's Nuclear Activities (Proc. Conf. Ottawa, 2005), CNS, Toronto (2005) Paper 5054 (CD-ROM).

Annex I–4

UNITED KINGDOM: MIGRATION OF NIREX LETTER OF COMPLIANCE (LOC) RECORDS ONTO ARCHIVE GRADE PAPER AND THEIR TRANSFER TO A MANAGED ARCHIVE FACILITY

I–4.1. INTRODUCTION

In November 2000, the UK decommissioning authority (NIREX) launched a programme of work with the objective of identifying issues relevant to the long term management of records [I–4.1]. Phase 1 of the work was a study of the media commonly employed, which highlighted areas that required further consideration prior to development of a long term records management strategy. NIREX subsequently used the outcomes of this work to contribute to the development of an industry-wide strategy and the basis of recommendations to waste packagers reviewing their own records management arrangements.

In Phase 2, NIREX investigated the practical aspects of preparing hard copy records for long term management. This included the migration of information from existing paper files to a specialist paper capable of being stored in a managed environment for hundreds of years.

The two phases of the project were undertaken as follows:

(1) Phase 1:
- A study of the characteristics of various recording media,
- Identification of best practice and techniques,
- Production of records media guidance;

(2) Phase 2:
- Identification of records management resources,
- Migration of NIREX records.

I–4.2. PHASE 1A: RECORDING MEDIA STUDY

NIREX engaged two specialist contractors to examine the issues relating to choice of media. The first focused on hard copy media, whilst the other undertook a review of electronic media. These two categories were defined as follows:

(1) *Hard copy* — including all types of paper, microform and solid substrates (metals, composites and minerals);

(2) *Electronic media* — including solid state memory, magnetic tapes, magnetic disks, optical disks, CD-ROMs and holographic memory (media relating to 'born-digital' information and that which is subsequently digitized were included).

The objective of this phase was to identify the intrinsic features and characteristics that could affect the long term stability of the medium and accessibility to the information. This necessitated an understanding of the optimum storage conditions. The outcome was a set of recommendations that could be taken forward as advice to waste records custodians and as input to the work developing a national policy.

I–4.3. PHASE 1B: IDENTIFICATION OF BEST PRACTICE

It was concluded that, whilst the type of media employed is an important consideration for records management, there are much broader management decisions to be made when adopting a long term information management strategy. Practitioners must look beyond the immediate issues of records management to consider how the information contained in the records will be created, recorded and ultimately recovered.

The outcome of this phase of the study suggested that fewer risks are encountered when good quality archive paper is used as the basis of an information system. The adoption of a radioactive waste information management system based on paper is consistent with that employed by ANDRA (the organization responsible for overseeing radioactive waste management in France). A national system has been established by ANDRA for hard copy radioactive waste records management that includes the use of both industry based and public archive facilities. Currently, the records associated with the waste disposed of at Centre de l'Aube and Centre de la Manche are copied onto archive grade paper and distributed to archives under the control of the local town council and the national records office in Paris. Copies of the records are also retained on-site.

Examples of best practice also showed that to guarantee, as far as possible, the longevity of the media and the information recorded on it, only high quality materials should be used, and that they should be stored in a controlled environment under a strict management regime.

I–4.4. PHASE 1C: RECORDS MEDIA GUIDANCE

On the basis of the outcomes of Phases 1a and 1b, NIREX produced a document that summarized their findings. This document was used as the basis for the trial that NIREX was to carry out in Phase 2. The document entitled 'The Long Term Management of Information and Records' was issued to waste custodians, in order to assist them in the development of local records systems.

I–4.5. PHASE 2A: IDENTIFICATION OF RECORDS MANAGEMENT RESOURCES

The objective of Phase 2 was to undertake an exercise that involved the migration of information contained in records located in the NIREX offices to a long term medium for storage in a managed archive facility. It was decided to undertake this trial on paper based records, as it was considered that this was the media used for many historical records. The intention was to:

(a) Identify a set of records requiring long term management;
(b) Identify the sources and costs of the required materials, equipment and labour;
(c) Develop a procedure for paper based information migration;
(d) Share lessons learned with the waste management community.

NIREX approached its Phase 1 contractors with a view to identifying potential suppliers of archive grade paper. A number of suggestions were made and Internet searches undertaken. Quotes were obtained from a number of potential suppliers and on the basis of cost, expertise and face-to-face meetings, a company that had experience in archiving supplies was selected. Although the company had not been involved in the management of information for the time periods envisaged, it was able to supply all the necessary materials. In addition, they suggested the use of so-called 'corrosion intercept bags'. The paper could be placed in these bags to inhibit the degradation of the media that could result from fungal growth and contamination, and also to protect the contents from external effects such as pollen, insects, dust and smoke particles, and water.

The supplier was able to demonstrate experience of working with museums and archives, and was used to advise companies on the optimum methods of preserving artefacts and paper documents. However, they did not have the resources necessary to undertake the copying and indexing of the letter of compliance (LOC) records.

The following materials were supplied:

— Archive grade acid-free paper;
— Purpose designed archive boxes;
— Corrosion intercept bags;
— Archive box labels.

I–4.6. PHASE 2B: MIGRATION EXERCISE

A set of records for the exercise was identified by NIREX. These records contain information that is expected to be of value to future waste custodians. Access to the information over a period of at least 100 years is anticipated. The information exists in both hard copy form (letters, specifications and reports) and electronic form (correspondence, photographs and spreadsheets), but only the hard copy records were included in the migration exercise.

The records, totalling about 30 linear metres of shelf space are contained in box files and are routinely accessed. As a result, some records have become lightly damaged through, for example, handling and sheets of paper being stapled together. The paper used is ‘standard’ recycled office paper and the box files are constructed from card with metal fixings. Other materials are contained in the files such as plastic folders, photographs, blueprint drawings, treasury tags, paper clips and adhesive tape.

The copying was to be undertaken on a dedicated refurbished digital copier. The supplier was requested to ensure that the copier was free of any cleaning and lubricating chemicals that could potentially contaminate the paper and interfere with its longevity. The toner used was a ‘carbon black’ based product (as opposed to a dye): this was specified because of its excellent long term stability, fastness and adhesion.

The copier was used exclusively for the exercise in order that the standard of cleanliness was preserved and contamination from other materials prevented. Use of the copier by unauthorized personnel was prevented by the application of a security code. The copier was also located in a room that was secured with a standard combination lock. During the period of the exercise, there was no requirement for maintenance, but discussions were held with the supplier who was informed of its use and the particular requirement that no chemicals were to be used that could potentially damage the archive paper.

Only files that had been closed (where it was expected that there were to be no more paper records added) were migrated — these amounted to about 300 box files (about 130 000 sides of A4 paper). The contents of these files varied and included some records that were larger than A4, so that these were scanned and reduced to A4 for convenience. However, it was recognized that some detail may well be lost on the reduced size record (original copies were retained in the files). The contents of each file were to be copied, single sided, onto the A4 size archive paper and placed into corrosion intercept bags. Care was taken not to overfill the bags and to ensure that they could be manually sealed.

The bags and their contents were then to be placed in specially designed storage boxes, constructed from the same materials as the paper and free of any component materials that could interfere with the paper (e.g. metal staples). The boxes are made of a dense cardboard that gives limited protection against fire (although they are not fireproof) and water.

Two sets of sample archive boxes were produced. The purpose of these samples was to enable NIREX personnel to monitor the state of the records deposited at the archive facility without having to disturb the master set. In addition, one set was used during the migration exercise to provide assurance of the process and confirm the quality and consistency of the materials.

Research was conducted by NIREX into a number of archive facilities where the records could be stored for the long term. The principal requirements were:

— Security;
— Appropriate environmental conditions;
— Appropriate storage shelving;
— Controlled access;
— A ‘double knock’ fire suppression system;
— Company stability and security;
— Cost.

A multinational archives company was selected on the basis that they could meet NIREX requirements in full at a reasonable cost. A security audit, of the company’s facility at Birmingham, was undertaken by the NIREX Facilities and Security Manager, and a full report provided to the Office of Civil Nuclear Security (OCNS), who endorsed the findings. The NIREX contracts department also undertook some research, to provide assurance that the company was financially stable with an acceptable track record in archives management.

The master copies and sample sets were to transferred from NIREX to the archives facility in three batches. This ensured that there was a compromise between transport costs and storage of the records in an uncontrolled environment at the NIREX offices.

An operating procedure was written for use by the operators and their management. This covered all aspects of procedure, materials control, recording and checking.

I–4.7. MIGRATION EXERCISE COSTS

A quote was obtained from an external supplier for the supply of all materials and labour. The company selected did not normally supply labour for such activities but was willing to provide it, through a third party, on this occasion. The quote came to £35 000, with the labour being almost 50% of this. It was therefore decided that NIREX would provide the labour under existing arrangements. This also had the advantage that the original records could remain within the NIREX building, that training was minimized, that additional security checks were not required and that the staff possessed an intrinsic knowledge of the material. It is believed that time will have been saved in dealing with queries.

The costs (at 2005 prices) were as follows:

— Raw materials, £6300;
— Equipment, £7000;
— Copying, £617;
— Archive, £343;
— Labour, £3234.

The total cost for the exercise was therefore £17 494.

There are, of course, ongoing costs associated with the storage of the copied records at the archives facility, which are currently approximately £100 a month.

I–4.8. MIGRATION EXERCISE FINDINGS

The process for copying, referencing, packaging and transporting records appeared to work very well, although the task did take a little longer to complete than was originally envisaged. All the identified records have been copied and transferred to the archives facility in Birmingham, where they will reside for the foreseeable future.

Having identified the records for copying, the process worked well. Box files were transferred to the copying room where they were reviewed for completeness, and existing binding and staples removed. The copies were made and then re-bound. The latter task was found to be very time-consuming, and this contributed to the additional time required to complete the exercise.

Some additional effort was necessary to index the records. The archive facility's records database was used to register the files prior to transferring them to Birmingham. The database is a convenient means for checking the location of archive files, but some advice from the NIREX packaging team was required to provide appropriate keywords and references in order that files can be quickly identified in the future.

The industry uses a great deal of jargon and abbreviations are profuse. Where possible, these were not used in any referencing, and glossaries were provided in the archive boxes where necessary. Some of the original records were themselves poorly copied and, in a few cases, text was found to be missing. It is therefore an important lesson that original records must be carefully checked and, where necessary, reproduced to ensure clarity.

The room used for the copying was relatively small (approximately 3 m × 3 m) and, although it was equipped with air conditioning, it became quite hot. The amount of space required for file sorting, record preparation and copy compilation was also limited: a larger room would have been more comfortable.

REFERENCE TO ANNEX I–4

[I–4.1] UPSHALL, I., Migration of NIREX Letter of Compliance (LoC) Records onto Archive-Grade Paper and their Transfer to a Managed Archive Facility, NIREX, Harwell (2007).

Annex I–5

UNITED STATES OF AMERICA: A SUMMARY OF US RECORD KEEPING REQUIREMENTS FOR DECOMMISSIONING PROJECTS

I–5.1. INTRODUCTION

The NRC has formal requirements regarding record keeping and records management specifically addressing decommissioning projects. These requirements vary slightly depending on the nature of the nuclear facility or of nuclear materials licensed for a particular location. The regulations are somewhat scattered among the various parts and chapters of NRC regulations including: 10 CFR: 10.2108, 20.2101, 20.2110, 30.51(c)(1), 40.36(f), 40.61(c)(1), 50.75(g), 70.25(g), 70.52(i)(1) and 72.30(d). There is, however, a single unifying concept that underlies all of these regulations. That concept is that record keeping for decommissioning is ultimately record keeping for radiation protection. All requirements lead back to keeping meticulous, verifiable and accurate records concerning radiation protection. Reference [I–5.1] provides a link to all 10 CFR 20 regulations.

The NRC regulatory requirements for decommissioning record keeping (i.e. a decommissioning records management programme) have been brought together and synthesized in an NRC guidance document entitled Consolidated NMSS Decommissioning Guidance, issued in 2003 as NUREG 1757 [I–5.2]. Volume 3 of this reference contains universally applicable guidance for all decommissioning projects with respect to records management obligations.

The following sections of this annex summarize and quote liberally from the guidance given in Ref. [I–5.2], as relevant to the topics of this report.

I–5.2. THE PURPOSE OF DECOMMISSIONING RECORDS MANAGEMENT

The purpose of the NRC's record keeping requirements is to provide an adequate knowledge base of the radiological conditions of a facility in order to enable decommissioning planning. This information will serve to facilitate decommissioning by minimizing occupational exposure and reducing the risk of any public exposure. The purpose of decommissioning records is to keep and maintain information concerning contamination remaining from spills or other occurrences and to maintain up to date drawings of both (a) restricted areas where radioactive materials are used or stored and (b) inaccessible areas, such as buried pipes, which might have been in contact with radioactive materials, so that this information can be used when planning for decommissioning.

I–5.3. GENERAL REQUIREMENTS

The general requirements for record keeping for decommissioning projects are:

(a) The location of decommissioning records must be clearly identified and designated to contain records and information important to safe decommissioning.
(b) Information related to decommissioning need not be submitted to the NRC as it is collected and filed, but the necessary documents must be maintained in appropriate files and be available for inspection upon request by the NRC.
(c) Pertinent documents, such as licensee operating procedures and incident reporting requirements, should specify the type of information to be kept and the means for retention and updating of records.
(d) Records may be originals, copies or clear and specific references to documents in other files. Computerized records systems may be used, provided the other provisions of this guidance (e.g. provisions for retrievability and protection against damage) are followed.
(e) The records must be protected against tampering and loss (e.g. fire, theft or misplacement). The records should be updated as necessary, at least annually, to include pertinent new information such as recent unusual occurrences or facility modifications.
(f) There should be provisions for efficient retrieval of the records at the time of decommissioning so that the records can be used as part of decommissioning planning.
(g) Licensee operating procedures should contain a clear definition of responsibility for collection, retention, maintenance, updating and recall of decommissioning records.
(h) Decommissioning records should be reviewed by licensee management, at least annually, to ensure their completeness and ability to serve their intended function.

I–5.4. CONTENT REQUIREMENTS FOR DECOMMISSIONING RECORDS

Decommissioning records must include all records regarding spills and other unusual occurrences involving the spread of contamination in and around the facility, equipment or site. The records may be limited to instances when contamination remains after any cleanup procedures or when there is a reasonable likelihood that contaminants have spread to inaccessible areas, as in the case of possible seepage into porous materials such as concrete, and that the records must include any known information on involved nuclides, quantities, forms and concentrations:

(a) The records should contain a description of the spill or occurrence (including the date), cleanup activities taken and the location of the remaining contamination. Inaccessible areas would be areas beyond those normally encountered in operations, such as cracks in concrete, seepage into porous material such as concrete, wood or tiles, seepage into equipment and components, or areas behind, below or obstructed by equipment or structures. The records should contain sketches, diagrams or drawings marked to show areas of contamination and points where radionuclide and radiation measurements were made.
(b) The records should contain information related to site characterization, including information on radiological spills on the site, residual soil contamination levels, principal contaminant radionuclides, on-site locations that may have been used for burial of radioactive materials, and any problems with hydrology and geology if the site contained or still contains settling ponds, lagoons or other potential sources of groundwater contamination.
(c) As noted above, the records are to clearly indicate the specific radionuclides involved and the locations, quantity, form and concentration of the radionuclide contamination, where known, and the basis for this information.
(d) Records on contamination that could contribute to exposure or have an impact on decommissioning methods, costs or radiation exposures should be included in the record file.

The decommissioning records must include as-built drawings and modifications of structures and equipment in restricted areas where radioactive materials are used or stored and the locations of possible inaccessible contamination. Normal facility as-built drawings are acceptable. If the records reference other required drawings, each relevant document need not be indexed individually. If drawings are not available, appropriate records of available information concerning these areas and locations are to be substituted:

(a) Drawings of restricted areas where radioactive materials are used or stored should include drawings showing the location of structures, systems, equipment and components in restricted areas as defined in NRC regulation 10 CFR 20.1003.
(b) Drawings of areas of possible inaccessible contamination should include buried pipes or other areas obstructed by equipment or structures.
(c) If other drawings are referenced, it is sufficient to reference the general category of drawings being referenced (e.g. drawings of a particular laboratory location or facility structure or equipment) and the specific location where those drawings are kept (e.g. the facility's specific file number).
(d) If drawings are unavailable, appropriate records of available information may be substituted, including written descriptions of particular areas, recent sketches or photographs.
(e) Drawings should be maintained and should be updated as systems, components and structures are modified or added. Old or superseded drawings must be retained if they contain information relevant to potential locations of contamination.
(f) To ensure that previously used work sites are not forgotten if they are inactive when final decommissioning occurs, the records should include information about all locations where radioactive operations were ever performed during the life of the facility, including a list of what licensed materials were handled, a general description of the operations performed, and typical contamination and radiation levels during operations.
(g) To provide a baseline history of background radiation levels prior to work with radioactive materials, the records should include surveys and isotopic analyses of building materials and soil samples made prior to initial use of new facilities or existing facilities not previously used for work with radioactive materials. This information can be used to verify the actual contribution of licensee operations to contamination and radiation levels at decommissioning.

Except for radionuclides and materials excluded by regulations, a list of the following must be maintained and updated every two years:

(a) All areas designated and formerly designated as restricted (under NRC regulation 10 CFR 20.2108);
(b) All areas outside of restricted areas that require documentation (under NRC regulations 10 CFR 30.35(g)(1), 40.36(f)(1), 70.25(g)(1) and 72.30(g)(1) (respectively));
(c) All areas outside of restricted areas where wastes have been buried, as documented under NRC regulation 10 CFR 20.2108;
(d) All areas outside of restricted areas that contain material, which if the licence expired, would require remediation to meet the criteria in NRC regulation 10 CFR Part 20, Subpart E, or application for disposal under 10 CFR 20.2002.

REFERENCES TO ANNEX I–5

[I–5.1] NUCLEAR REGULATORY COMMISSION, NRC Regulations Title 10, Code of Federal Regulations (2007), http://www.nrc.gov/reading-rm/doc-collections/cfr/
[I–5.2] NUCLEAR REGULATORY COMMISSION, Consolidated Decommissioning Guidance, NUREG 1757 (2007), http://www.nrc.gov/reading-rm/doc-collections/nuregs/staff/sr1757/

Annex II

EXAMPLES OF LESSONS LEARNED

The following examples present lessons learned, some brief technical details of each decommissioning project and a description of the problems encountered. The situations described are typical of the difficulties that can arise when planning or implementing decommissioning activities for which the available RMSs proved to be inadequate. The information presented, although pointing towards typical record management issues prevailing in the long term, is not intended to be exhaustive. The reader is encouraged to evaluate the applicability of the lessons learned to their specific decommissioning project. The general categories of problem and the relevant section in which they are discussed are shown in Table II–1.

TABLE II–1. CATEGORIES OF PROBLEM AND THE RELEVANT SECTION IN WHICH THEY ARE DISCUSSED

Problem category	Section
Inappropriate storage media, location or environment	II–4, II–15
Records destroyed or never moved to archives, or inadequate records placed in archives	II–1, II–2, II–6, II–9, II–10, II–11
Inadequate configuration control	II–3, II–5, II–8, II–12
Inappropriate records preservation method	II–7, II–13, II–14

Annex II–1

IMPROPER STORAGE AND MAINTENANCE OF RECORDS, OAK RIDGE SITE, USA

II–1.1. PROBLEM ENCOUNTERED

During reorganization and dissolution of an Oak Ridge National Laboratory (ORNL) office while making the transition from one contractor to another, the record copy of an external assessment report of an ORNL programme was destroyed. The external assessor, who was reassigned to a different organization, discarded their copy of the report because it was a non-record copy [II–1.1].

II–1.2. LESSONS LEARNED

During reorganization and personnel reassignment, managers should ensure proper storage and maintenance of records.

REFERENCE TO ANNEX II–1

[II–1.1] UNITED STATES DEPARTMENT OF ENERGY, Improper Storage and Maintenance of Records, Lesson ID: B-2001-OR-X10UTB-1002 (2001), www.hss.energy.gov (available upon subscription).

Annex II–2

INADEQUATE COMPUTER BACKUP PROCESS RESULTING IN DATA LOSS, US SITE

II–2.1. PROBLEM ENCOUNTERED

An Information Systems (IS) contractor employee arrived to install a docking station and transfer files from a user's desktop computer to a new laptop. She asked the user what files he needed to save. The user told her which files contained his work, and then she proceeded to change the equipment within 30 minutes. The user went into the C drive on the new computer to access his work and was unable to retrieve a number of working files. The user immediately contracted the IS organization concerning this issue. He was later informed that his computer had been sanitized within an hour of leaving his office and that there was nothing that could be done to retrieve his files. Several man-hours of work were wasted and the records were permanently lost [II–2.1].

II–2.2. ANALYSIS

The user did not identify all of the information that they wanted to save. The user was not aware of all the areas where they had saved files beyond those reported to the contractor. The contractor did not investigate the possibility that the user had files they wanted to keep located in a number of places on their hard drive. The computer removed from the user's area was sanitized before the user had the opportunity to verify that they had access to their old files on the new computer.

II–2.3. LESSONS LEARNED

All the files on a computer should be transferred to a read/write CD during computer exchanges to ensure that files not identified by the user as necessary will be available once the computer has been sanitized. Users should be required to check that the files have been uploaded from the disk, to ensure that they are all present and accessible before former computer drives are sanitized.

Computers destined for sanitizing should have all the information on them backed up on a read/write CD, reloaded onto the new computer and verified by the user before the computer is sanitized.

REFERENCE TO ANNEX II–2

[II–2.1] UNITED STATES DEPARTMENT OF ENERGY, "Inadequate computer backup process results in data loss", Lessons Learned Database, Lesson ID: 2001-NV-NTSBN-015 (2001), www.eh.doe.gov/DOEll/ (available upon subscription).

ANNEX II–3

OUTDATED DOCUMENT RETRIEVED USING A WEB BROWSER, HANFORD SITE, USA

II–3.1. PROBLEM ENCOUNTERED

During the week of 1 March 2004, a Hanford employee discovered that a procedure they had accessed with their web browser was outdated. The procedure had been updated on the web server almost two weeks earlier.

II–3.2. ANALYSIS

An investigation into this problem revealed the following: the user's web browser had been changed from the default setting and was therefore not set to automatically check for newer versions of stored pages on each visit to a web page. Their computer had cached the outdated web page. When they went back to that page later, their web browser recalled the file from their computer's cache (computer disk space for holding recently visited sites/documents) instead of from the server where the current version was stored.

Computer users can select browser settings that automatically prevent documents being refreshed on opening under some conditions. The user may think they are calling up the latest version of a procedure or other document, but it may not actually be current if they have not refreshed it from the server either manually or automatically. Web pages, however, can be set to override those user settings by preventing documents from being stored in the user's cache (Fig. II–3.1).

This event had no safety consequences, but a similar occurrence could potentially cause problems if the document of interest had been changed recently to resolve a safety issue.

II–3.3. LESSONS LEARNED

While workers have an obligation to ensure that they are using the latest version of a document, they generally assume that they will receive the latest approved version when accessing a document from the web. This is typically a valid assumption because the Hanford site default browser setting forces the data to be refreshed each time a web page is accessed. In this case, a procedure

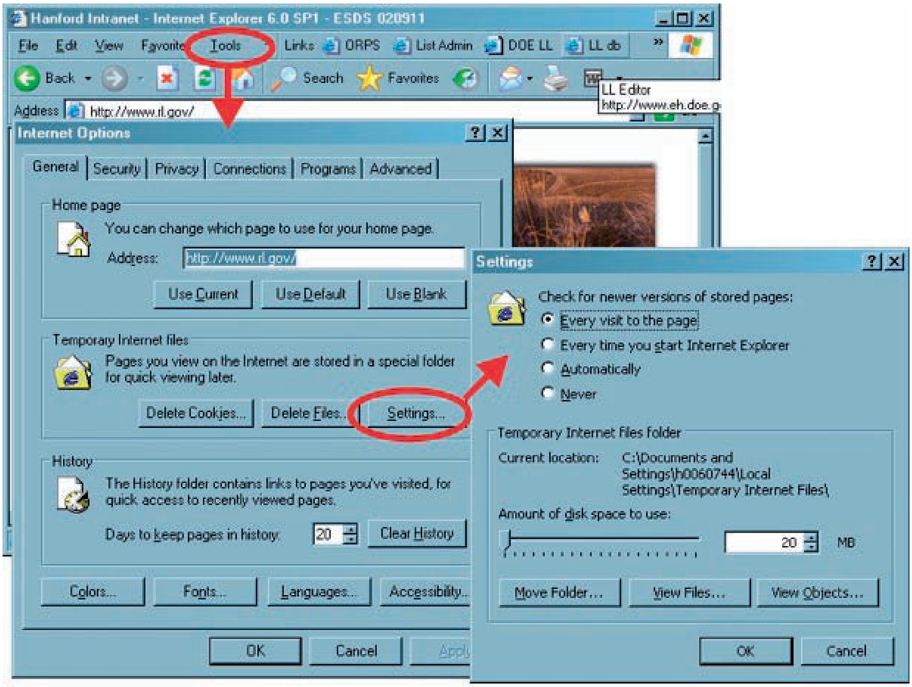

FIG. II–3.1. Avoiding outdated documents when using a web browser.

user's browser setting had been changed from the default setting. As a result, they unknowingly accessed an outdated procedure because the older version had been cached on their system by the web browser.

Site administrators should consider restricting users' ability to change browser settings from the configuration that forces a refresh procedure every time a web page is visited. Implementing a system to periodically reset them to the default setting is another option.

For web sites where referenced documents change on a frequent basis, changes can be implemented to prevent workstations from caching information. Such changes will force all users accessing that web site to obtain the latest versions of documents regardless of the client browser setting.

Web authors and those responsible for reference web servers (e.g. procedure web sites) should review the information in the technical supplement attached to Ref. [II–3.1], and implement the appropriate techniques listed there for preventing documents from being stored in the user's cache.

REFERENCE TO ANNEX II–3

[II–3.1] UNITED STATES DEPARTMENT OF ENERGY, "Outdated document retrieved using a web browser", Lessons Learned Database, Lesson ID: 2004-RL-HNF-0015 (2004), www.eh.doe.gov/DOEll/ (available upon subscription).

Annex II–4

CRITICAL RECORDS LOST, US SITE

II–4.1. PROBLEM ENCOUNTERED

A laptop computer hard drive failed. The most critical information lost was a database that contained the qualified supplier list. The qualified supplier list had been saved to a public drive. When information systems staff were contacted, the user was told that items on the public drive were not backed up.

II–4.2. ANALYSIS

The user was under the assumption that items saved on the public drive were backed up. This was not the case. Attempts were made to retrieve critical documents, but the attempts failed. All documents saved to the failed hard drive were lost and had to be recreated. A qualified supplier list was not issued for that quarter, and a new database had to be recreated. Many years of historical data on all suppliers that had been listed in the database were lost. The user was not able to recreate the historical supplier database since the files had been destroyed.

Critical data are now stored on a separate removable disk drive and will eventually be backed up on a public drive as part of a larger server.

II–4.3. LESSONS LEARNED

It should be ensured that personnel understand the limits of public drives and that all work critical to mission success is saved on separate media. Personnel should be aware of the possibility that national institutions (in the USA the National Nuclear Security Administration Cyber Forensics Center) have the capability to recover lost or corrupted data from digital media [II–4.1].

REFERENCE TO ANNEX II–4

[II–4.1] UNITED STATES DEPARTMENT OF ENERGY, "Critical records lost", Lessons Learned Database, Lesson ID: 2004-NV-NTSBN-001 (2004), www.eh.doe.gov/DOEll/ (available upon subscription).

Annex II–5

INCOMPLETE UNDERGROUND UTILITY INFORMATION ON CONSTRUCTION DRAWINGS, HANFORD SITE, USA

II–5.1. PROBLEM ENCOUNTERED

Project W-519, Privatization Phase I Infrastructure, provided underground raw and sanitary water, electric power utilities, roads and effluent drain piping for the verification facility to be constructed near the 200 East areas at Hanford. During the design phase of the project, research of existing drawings was conducted to locate existing buried utilities near the W-519 water pipe routes. The results of that research were used to develop the plan and profile drawings for the new water pipes. Scanning for underground utilities was performed to provide the latest information on utilities and to verify the locations of known existing utilities for a portion of the project.

Because of schedule and project funding constraints, the project drawings were released for construction with only 75% of the ground penetrating scans for buried utilities on the pipeline route complete, with findings recorded on the drawings [II–5.1]. This prevented the 'released for construction' drawings from depicting the existence and locations of some buried utilities. When the scanning was completed in a highly congested underground tank farm area, Canton Avenue and Eighth Street below C Farm, additional utilities were discovered; however, construction drawings were not modified at that time to include the additional information.

The incomplete 'released for construction' drawings were issued as part of a contract bid package, the contract was awarded and the contractor was given a notice to proceed. Prior to work proceeding in the areas where scanning data were missing, the construction staff noted that scanning data were missing from the drawings. The released drawings were then checked against the latest scan drawings, which showed additional information about utilities underground. The released drawings were revised by means of a design change notice (DCN) to show the missing buried utilities. Once all the utilities had been identified, work proceeded without incident.

II–5.2. ANALYSIS

The W-519 construction is performed by fixed price (FP) contracting. The FP contract requires hand excavation on either side of buried utilities. Adding buried utilities to drawings after a contract has been awarded constitutes a change in scope and may entitle the contractor to charge for additional costs incurred. Permits are required by Hanford procedure No. 473 for underground excavations at Hanford. The permitting process includes steps to verify the locations of existing underground utilities, including research into drawings. Those drawings must be accurate in order to prevent the permit process being undermined.

II–5.3. LESSONS LEARNED

Design engineers must confirm that the latest information and ground scanning information is identified on drawings prior to them being issued. The surveyor who performs the underground scanning must sign the drawings or issue a signed composite drawing to ensure that all the information scanned is depicted correctly and that the limits of the scan are identified. If funding and schedule constraints lead to a design being released prior to completion of scanning, the drawing should note this deficiency, and the scanning information should be added to the drawing by means of a DCN as soon as it is available.

Excavate over all existing utilities at the proposed crossing points to verify the actual location prior to finalizing the design, to minimize interference. This is especially important where the elevation of the utility could affect the design. Constructional drawings should include all the underground utilities as determined by complete research of existing drawings, underground scans and, where appropriate, excavations.

REFERENCE TO ANNEX II–5

[II–5.1] UNITED STATES DEPARTMENT OF ENERGY, "Incomplete underground utility information on construction drawings", Lessons Learned Database, Lesson ID: 2000-RL-HNF-0013 (2000), www.eh.doe.gov/DOEll/ (available upon subscription).

Annex II–6

LEGACY RADIOLOGICAL CONTAMINATION IMPROPERLY POSTED, BROOKHAVEN NATIONAL LABORATORY, USA

II–6.1. PROBLEM ENCOUNTERED

After Energy, Environment, and National Security (EENS) personnel vacated building 820A at Brookhaven National Laboratory (BNL) Plant Engineering (PE), personnel prepared the area for its next occupant. A double walk-in type hood on the south side of the building was scheduled for removal. Plant Engineering personnel contacted the previous EENS user concerning process knowledge about the hood, noting an area of the hood covered with duct tape.

According to an EENS researcher, the hood had become contaminated sometime prior to 1985 while others were using it in building B-318. The contaminated areas were covered with duct tape, consistent with the usual engineering controls at that time. The hood was disassembled in building B-318 and moved to its present location (B-820A) in 1985. However, the hood was stored in sections for some time, and the EENS user was neither informed of the marked area nor was this area noticeable in its stored position [II–6.1]. In 1988, the hood was then reassembled at its present location, at which time the EENS user noticed the taped area. Surveys, requested by the new user, were conducted in 1988 by a radiological control technician (RCT), who indicated that the fixed contamination was not a problem and, presumably, in accordance with the posting requirements at the time. Although actively used in building B-820A, no radiological work has ever been conducted in this hood since 1988. Notwithstanding this fact, the radiological controls in place since 1985 were not consistent with current requirements.

A new survey was requested, in which levels of fixed contamination were confirmed. The hood was posted as a radioactive material area, and the contaminated panels were scheduled for analysis and subsequent removal. This event resulted in the generation by BNL of a Radiological Awareness Report and a USDOE Occurrence Report.

II–6.2. ANALYSIS

Two extensive laboratory-wide studies had been conducted by BNL, one in 1990 that included an in-depth radiological survey of facilities; the other in

1997 in which process knowledge of legacy contamination was acquired through interviews with both present and past employees. Although much information on legacy contamination areas was gleaned from these two studies, gaps existed in the implementation process. Situations such as the above should have been identified and clearly documented in a laboratory-wide report, and follow-up actions subsequently taken to reflect current requirements and/or orders. This was not the case for this particular instance, because the process knowledge on the B-820A hood was not documented.

Accordingly, fixed contamination was known by some to exist in the subject hood since 1985, and the area had been marked with duct tape, albeit not posted, which presumably was in accordance with the requirements for radiological control at that time. However, no tracking and follow-up was performed for this legacy contamination, as indicated by the lack of posting and documentation.

The EENS user, aware of the contaminated area, was lead to believe that adequate safeguards had been in place since 1985. No additional administrative controls were thought to be needed and no follow-up surveys were considered to be required, since no radiological work had ever been conducted in the hood in building B-820A since 1988.

II–6.3. LESSONS LEARNED

Corrective actions instituted at the laboratory level include surveying all equipment being accessed or relocated whose past use is unknown or suspect. In addition, the information provided in the facility reviews is being used to ensure that previously identified areas of fixed contamination have the proper postings.

The laboratory should update its radiological ‘hazard footprint’ for conditions that are not directly related to achieving the laboratory mission and that have not been transferred to environmental management for disposition and resolution. As the footprint evolves, management processes can then be developed and action can then be taken to address specific issues.

Plans for implementation of new standards or orders should take into account in a uniform and consistent way the possible implications connected with addressing legacy issues and the ensuing programmatic impacts.

REFERENCE TO ANNEX II–6

[II–6.1] UNITED STATES DEPARTMENT OF ENERGY, “Legacy radiological contamination improperly posted”, Lessons Learned Database, Lesson ID: 2001-CH-BNL-EENS-002 (2001), www.eh.doe.gov/DOEll/ (available upon subscription).

Annex II–7

CHARACTERS CONVERT INACCURATELY BETWEEN WORD PROCESSORS, HANFORD SITE, USA

II–7.1. PROBLEM ENCOUNTERED

Documents converted between word processing software packages may contain incorrect characters caused by inaccurate mapping between character sets. Some fractions may not convert accurately [II–7.1]. This could create safety issues if operating procedures were released with erroneous information. For example, the fraction 1/4 in WordPerfect® converts to a value of three (3) in Word. An operating procedure that states, “Open valve A-45, Holding Tank Fill Valve, 1/4 turn.” would read “Open valve A-45, Holding Tank Fill Valve, 3 turn.” after conversion.

II–7.2. ANALYSIS

There are two problems. One is related to font substitution and the other to the way Word® converts symbols into characters. The problem related to font substitution is an issue with any Windows application. As technology improves, so also have the character definition standards. Word® uses a relatively new character definition standard called Unicode that assigns a unique 16-bit number to each symbol or character. WordPerfect® 5.1 uses a character set called OEM (original equipment manufacturer). Older Windows® applications use a standard character set called ANSI (American National Standards Institute). The three standards are not the same for all characters, especially for symbols and characters beyond the normal letters and characters on the keyboard. A word processor opening a file with a character set that it does not use may not map each character to the correct symbol in its own set. Users opening a document on a system that does not have the same font set as that used in the original document may have unexpected results on their screens such as boxes or other strange characters, owing to font substitution.

The other problem arises from the way Word® treats some symbols as codes and others as characters. The character symbols are more likely to change when the document base font is changed. The character may change to an empty box or to a character from a different font set. To prevent this, the character symbol should be changed to a code symbol. Any document with any character set created using any version of WordPerfect® may be susceptible to this problem. Other word processors may also make these errors.

II–7.3. LESSONS LEARNED

Documents converted from WordPerfect® into Microsoft Word® may contain errors in character mapping that could cause serious problems and potentially unsafe conditions, especially with operating procedures and other safety related documents. All converted documents must be carefully proofread to ensure that the documents are accurate and complete before they are released for use. It is possible to write a MACRO for Word® that will replace many character symbols with the appropriate code symbols to minimize the impact of the conversion problem. Microsoft Inc. is also addressing the issue with a 'hot fix'.

The lesson learned is *always* to proofread a document carefully after a conversion.

REFERENCE TO ANNEX II–7

[II–7.1] UNITED STATES DEPARTMENT OF ENERGY, "Characters convert inaccurately between word processors", Lessons Learned Database, Lesson ID: 1999-RL-HNF-0018 (1999), www.eh.doe.gov/DOEll/ (available upon subscription).

Annex II–8

IMPROPER RECORD KEEPING, IDAHO NATIONAL ENGINEERING AND ENVIRONMENTAL LABORATORY, USA

II–8.1. PROBLEM ENCOUNTERED

On 26 May 1999, a utility operator was performing a lockout/tagout (LOTO) on a diesel fire pump. One isolation method that the operator had chosen was the removal of the positive battery cable from the engine. The mechanic who requested the LOTO suggested an alternative isolation point, which later proved to be inadequate. The inadequate LOTO isolation point was abandoned and the original (battery cable) choice was physically locked out. As a result, the LOTO record sheet had multiple corrections in the location block for this isolation point. The utility foreman and utility operator agreed that the LOTO record was difficult to understand with the corrections and agreed that it should be replaced. Shift change was approaching and the utility operator requested that the foreman have the day shift operator rewrite the record sheet and initial for him in the ‘posted by’ block for the engine battery cable isolation entry. The foreman explained to the day shift operator what had transpired and directed the day shift operator to rewrite the record sheet to clean it up. The day shift operator rewrote the LOTO record sheet and placed the initials of the original operator in the ‘posted by’ block for the positive battery cables and the ‘lock box’ block. The original record sheet was discarded. That day, a supervisory ‘walkdown’ of the LOTO was conducted and it was found that, although the positive battery cables had been removed and locked, the danger tag had not been posted. The danger tag was lying on a control panel in the vicinity.

II–8.2. ANALYSIS

The record keeping practices associated with this LOTO evolution contained the following problems: the new record was not annotated to indicate the existence of an original and the original record was subsequently destroyed [II–8.1]. The employee who created the new record transferred the initials for another individual without a clarifying annotation. The signed-off (initialled) action had never been completed. A company procedure provided instructions for transferring signatures in the absence of the originator. The utility foreman did not ensure the rewriting process was conducted in accordance with this procedure.

II–8.3. LESSONS LEARNED

Management control procedures governing quality records should be reviewed, focusing on guidance for rewriting a lost or damaged (e.g. oil soaked or torn) quality record. The process and facility procedures that direct the creation of quality records should be reviewed for clarity and flow-down requirements. Employees should be trained or retrained in appropriate procedures. All employees should understand that improper record/log keeping could lead to unsafe working conditions.

REFERENCE TO ANNEX II–8

[II–8.1] UNITED STATES DEPARTMENT OF ENERGY, "Improper record keeping", Lessons Learned Database, Lesson ID: INEEL-1999-379 (1999), www.eh.doe.gov/DOEll/ (available upon subscription).

Annex II–9

SHUTDOWN FACILITY BASELINE INVENTORY PRACTICES, OAK RIDGE SITE, USA

II–9.1. PROBLEM ENCOUNTERED

During routine inventory activities, additional material was discovered in building K-25. A documented safety analysis (DSA) identifies the total quantity of the material. The hazard analysis investigated only one specific form of the material identified. The additional material was of a form that was not fully analysed. Building K-25 was shut down in 1964. Since that time the facility has become a warehouse for discontinued USDOE operations. A baseline facility inventory conducted in 2000 to support DSA development was less than adequate. The size of the facility, with numerous types of containers and materials from many programmes and sites, combined with a lack of familiarity with the facility and infrequent making of a detailed inventory led to misidentification of the drums associated with the occurrence [II–9.1].

II–9.2. ANALYSIS

Large facilities that have been shut down for long periods of time are often used to house material from discontinued programmes. Typically during programme management, completion of project storage concerns is not adequately defined. If a programme ends due to lack of funding, the rigour with which the inventory has been made and the labelling done may not be adequate to allow for proper interpretation of data by personnel not directly associated with a project.

II–9.3. LESSONS LEARNED

Disposal of material and equipment should be properly planned for during the life of a programme. Disposition paths for the material should be identified as part of the procurement and planning process. If the material has a future use, it should be kept as part of the facility inventory. Shipping material from site to site is not recommended. If the material has no disposal path and must be relocated, a good inventory system should be developed and maintained to adequately track quantities, inspect containers and retain records. Prior to updating or revision of the facility safety basis, the adequacy, comprehensiveness and accuracy of the facility inventory documentation should be ensured. Additional inventory determinations should be made as deemed necessary. Prior to accepting a facility into a decontamination or decommissioning programme, project/facility managers should insist on a formal facility turnover. The turnover should be accomplished in accordance with current USDOE orders and include development of a deactivation/ transition plan to formally collect facility inventories.

Only personnel with enough corporate knowledge to properly identify equipment and material should perform baseline facility inventories.

REFERENCE TO ANNEX II–9

[II–9.1] UNITED STATES DEPARTMENT OF ENERGY, Shutdown Facility Baseline Inventory Practices, Lessons Learned Database, Lesson ID: B-2005-OR-BJCK25/K27-0301 (2005), www.eh.doe.gov/DOEll/ (available upon subscription).

Annex II–10

HISTORICAL SITE ASSESSMENT, SAXTON PWR USA

II–10.1. PROBLEM ENCOUNTERED

A competent historical site assessment (HSA) requires much time in reviewing records from construction era documents on up to the most recent plant records. Sometimes simply retrieving the records of interest can be daunting. Old records were sometimes filed using methods that have since been forgotten. This process can take a very long time.

Most plant records, particularly older ones, are generally brief and lacking of very much explanatory narrative. Log books and other similar records were maintained by individuals who were highly familiar with the operations being carried out, and they were written for the benefit of other individuals who were equally as familiar with the particular operation or process. Consequently, many entries will be quite brief and will contain operation-specific jargon to such a degree as to make it very difficult for an HSA reviewer to extract useful information from these sources.

II–10.2. ANALYSIS

When reviewing historical documents, it may be useful to obtain the services of someone who is familiar with the operations in question [II–10.1]. This type of individual may still be on the plant staff or may be available as a retiree or other former employee. In the case of Saxton, it was very useful to interview individuals who had actually taken part in various phases of decommissioning, in order to gain first-hand perspectives on the process.

II–10.3. LESSONS LEARNED

Old records may generate as many questions as they answer.

REFERENCE TO ANNEX II–10

[II–10.1] WILLIAMS, M.S., CARMEL, P.G., "What you don't know can hurt you", in Waste Management 2000 (Proc. Int. Symp. Tucson, 2000), Waste Management Symposia, Inc., Tucson, AZ (2000).

Annex II–11

GKN DODEWAARD, THE NETHERLANDS

II–11.1. PROBLEM ENCOUNTERED

When the GKN plant at Dodewaard was shut down, staff started to clean out personal archives on the basis of their own ideas of what was important. Management stopped this process as soon as they became aware of it. Soon afterwards, the archive project was started. It is unclear if important information was destroyed.

After completion of the PSE phase, staff started to destroy information created during that phase. This was only stopped after a lot of information had already been destroyed. Staff gained the impression that all necessary information for operating the safe enclosure would be provided by the contractor who prepared the plant for safe enclosure.

During the first phase, the only copy remaining of a report entitled ‘Evaluation of the Construction of the Plant’ was saved at the last moment. During the second phase, a report entitled ‘Repairs of Concrete Walls and Cracks in Walls’, was found in a paper container ready to be destroyed. This report was found to be the only report on this matter and should have been in the official archive.

II–11.2. SOLUTION FOUND

Staff leaving the station were ordered not to destroy official documents by themselves, but to hand these in to the personnel of the archive group. This created a lot of extra work for this group but resulted in valuable information being saved.

II–11.3. LESSONS LEARNED

People do not in general understand the value of documents, as they do not realize that they may be in possession of the original or of the last remaining copy. Staff must not destroy documents on the basis of their own personal judgement. Destruction of documents should be done systematically by an archive group, on the basis of criteria that have been well defined by station management and the regulator.

ANNEX II–12

USE OF DRAWINGS DURING DECONTAMINATION AND DECOMMISSIONING, USA

II–12.1. PROBLEM ENCOUNTERED

On 26 January 2006 personnel realized that they were placing fissile material in an area of building K-1420 that was not approved by the Justification for Continued Operation (JCO) document that they were working under [II–12.1].

Work was ongoing in an approved area of building K-1420, classified as a hazard category 2 nuclear area within the facility, to ensure the absence of liquids. As workers used up all the space for arrays on the first floor in an approved area and, as space was limited for additional arrays on the first floor, approval was requested from the nuclear criticality safety organization to set up an array on the upper floor. Approval was given to use the upper floor. On 18 January 2006, posting for an array was established in what was thought to be an approved area on the upper floor, and bottles with fissile material were placed in the array. On 26 January 2006, an additional array was approved for this area. On 26 January 2006, at 14:30, questions were raised regarding whether or not this area was approved for storage of arrays, and it was pointed out that this was not actually an approved area. Work stopped at 15:00 on 26 January 2006 in building K-1420.

II–12.2. ANALYSIS

Several issues arise from this event. However, the driving force that caused it relates to control of drawings during decommissioning. The problem with drawings during decommissioning is that, since it is planned to remove a building, it is generally not considered economically sound to keep drawings updated as would be the case for buildings that are being constructed or operated. However, from a facility safety standpoint, the best set of drawings available is still needed as a starting point. These drawings have to be checked. All documents generated for that building need to use this same set of drawings as their basis.

II–12.3. LESSONS LEARNED

Some issues to consider related to use of drawings are:

(a) For decommissioning, locate or obtain the best set of drawings available for a building or facility. Ensure that these drawings are maintained in a formal drawing control programme.
(b) Consider using drawings that identify buildings by orientation; for example, by column and elevation or floor, as opposed to area or room. Whatever is selected, be consistent in all documents so as to avoid confusion.
(c) Consider labelling sections of the building and/or equipment with paint or placards. The individuals performing the decommissioning are generally not the previous operators and are therefore not qualified on the equipment in the building and are not as familiar with the building as previous operators. Labelling may avoid confusion.
(d) Ensure that all documents generated for that building or facility use the same set of drawings as their basis.
(e) As equipment is removed, consider using a 'red line' process rather than a formal as-built or drawings revision process.
(f) As drawings are no longer applicable owing to removable equipment, delete the drawings and retain them as records that will show that all equipment has been removed.
(g) As the building is being removed, use the same red line process, particularly for large buildings, until the building has been demolished. Then delete appropriate drawings and retain them as records to show what has been removed.
(h) Continue this process until there are no more active drawings for that building or facility.

As a generic lesson learned, develop project documentation on the basis of the best available set of drawings for a building or facility so as to maintain consistency and avoid confusion.

REFERENCE TO ANNEX II–12

[II–12.1] UNITED STATES DEPARTMENT OF ENERGY, "Use of drawings during decontamination & decommissioning (D&D)", Lessons Learned Database, Lesson ID: B-2006-OR-BJCETTP-0302 (2006), www.eh.doe.gov/DOEll/ (available upon subscription).

Annex II–13

EVOLUTION OF ARCHIVING APPROACHES, AECL, CANADA

II–13.1. PROBLEM ENCOUNTERED

In the late 1990s, a project was initiated to archive a set of facility records for long term preservation and use by future decommissioning teams. The project team scanned a collection of hard copy facility records into single page TIFF files, which were indexed and managed using stand-alone proprietary document database software. This software allowed for the creation of CD archive collections, which archived the electronic TIFF files, and an executable copy of the database software was used to search the index of the TIFF files. Multiple copies of the CDs were created for backup purposes. Once the archiving was complete, the original hardware and software used to create the CDs was no longer required and was abandoned.

In the 2000s, shortly after upgrading a user's PC to the Windows NT operating system, the decommissioning staff attempted to use the facility archive CDs to search for information about the facility, but the software would not run. It was discovered that the CD executable software would only run on a PC with Windows 95, and would only print to an HP LaserJet III printer. The single page TIFF files could be extracted from the CD, but without the database the process of matching the individual pages of a document would be extremely difficult. The software vendor had gone out of business and the software was no longer supported.

II–13.2. SOLUTION FOUND

An interim solution was to set up a stand-alone PC with a Windows 95 operating system and a LaserJet III printer to provide access to the electronic collection until an alternative electronic archive could be created. A project was undertaken to compare the CD collection and the existing hard copy collection, in order to ensure that the hard copy collection was complete. Once the hard copy records are confirmed, the files will be rescanned and indexed into the company RMS and an indexed microfilm backup of the hard copies created.

II–13.3. LESSONS LEARNED

It is unlikely that CD based archives will work well for long term (over ten years) archives due to ever-changing PC software and upgrading of equipment. Stand-alone and proprietary software should be avoided for long term archival projects. Documents should be archived to multiple page TIFF or PDF file format for long term storage, to ensure that the complete document remains intact. Regular and ongoing inspections and assessment of long term record archives should be performed to ensure the readability, access and usability of records.

Annex II–14

PRESERVATION PLANNING TO AVOID THE PROBLEM OF DIGITAL OBSOLESCENCE, UK

II–14.1. PROBLEM ENCOUNTERED

Although not a nuclear project, this problem encapsulates the issues relating to digital preservation and the speed with which hardware and software can become obsolete [II–14.1].

After William the Conqueror invaded England he had an inventory made containing lists of everything from towns to farms. This was called the Domesday Book, and it was produced on vellum (animal skin) in 1086 and it is still readable today at The UK National Archives, over 900 years later.

To mark the 900th anniversary of the original Domesday Book, the BBC launched the 1986 Domesday project. This consisted of thousands of photographs and maps combined with statistical, written and visual information to produce a record of Britain in 1986.

The project was recorded onto 30 cm laser disks and could be viewed with software running on BBC microcomputers. Less than 20 years later, not only are the 30 cm laser disks obsolete, but also the necessary hardware for them.

II–14.2. SOLUTION FOUND

Separate projects were launched by The National Archives and by Leeds University to rescue the data and the software that made up the 1986 Domesday project. This was only achieved because a surviving laser disk player was found, and still needed more than a year's effort by specialist teams.

II–14.3. LESSONS LEARNED

Firstly, the choice of hardware, software and media should reflect the expected duration of the records in the archive. Secondly, if the archive is built around electronic records, it is advisable to follow the OAIS reference model; this includes preservation planning, which covers issues such as migration of media, software or hardware. Finally, this demonstrates that the cost and effort of recovering even a modest number of complex records can be quite considerable when systems have become obsolete.

REFERENCE TO ANNEX II–14

[II–14.1] ARIADNE, Domesday Redux: The Rescue of the BBC Domesday Project Videodiscs, http://www.ariadne.ac.uk/issue36/tna/

Annex II–15

SELECTION OF ARCHIVE MEDIA, UK

II–15.1. PROBLEM ENCOUNTERED

This case is about a catastrophic failure of a four year old CD-ROM. The recording substrate has 'crazed', rendering the CD unusable and with the consequent loss of all recorded information.

II–15.2. ANALYSIS

Within the UK nuclear industry, CD-ROMs and DVDs are extensively used to store information, but users are often unaware of the quality of either the materials or the manufacturing process, thus exposing themselves to catastrophic and unrecoverable information loss. Furthermore, users are unaware of the damage that can be caused to CD-ROMs through inappropriate handling, storage and physical labelling.

II–15.3. LESSONS LEARNED

The appropriate selection of recording media is essential to preservation of information, as this is the way in which it is handled and the environment in which it is stored. Only media of known and respected provenance should be used and it should be regularly inspected, tested and the information contained migrated onto new media in line with a preservation plan.

GLOSSARY

The definitions below have been extracted from various sources and are applicable only for the purposes of this report. Definitions marked by an asterisk (*) have been taken from the IAEA Safety Glossary, Version 2.0, 2006 (http://www-ns.iaea.org/standards/safety-glossary.htm).

access control. Logical or physical limitation of access to information and information systems resources based on a need-to-know.

accountability. The property that permits tracing to their origins, through activity logs and other means, actions taken by people, devices or programmes.

archive. A well ordered collection of records to be maintained for a long time.

archiving. The preservation of the various versions and changes of records, in such a way that allows access to past revisions of documents and records.

backup. A copy of data held within an information system that can be used to restore the information in the event of an interruption; or the process of copying information from an information system to a secondary storage device.

database. An organized collection of records permitting the structured interrogation, storage, deletion and retrieval of information.

decommissioning. Administrative and technical actions taken to allow the removal of some or all of the regulatory controls from a facility (except for a repository or for certain nuclear facilities used for the disposal of residues from the mining and processing of radioactive material, which are ‘closed’ and not ‘decommissioned’).*

decommissioning plan. A document containing detailed information on the proposed decommissioning of a facility.*

decontamination. The complete or partial removal of contamination by a deliberate physical, chemical or biological process.*

design. The process and the result of developing a concept, detailed plans, supporting calculations and specifications for a facility and its parts.*

destruction. Process of eliminating or deleting records, beyond any possible reconstruction.

disaster recovery plan (DRP). A structured set of plans, work steps and responsibility assignments for the recovery to minimum levels of operational continuity, following a business interruption.

dismantling. The disassembly and removal of any structure, system or component during decommissioning. Dismantling may be performed immediately after the permanent retirement of a nuclear facility, or may be deferred.

document. Any physical item displaying information other than computer material or optical surveillance material. A document is a collection of information that is processed as a unit.

electronic material. Includes any computer monitor display or computer storage media, such as disks, tapes, diskettes and CD-ROMs but does not include computer printouts. (Computer printouts are considered to be documents.)

enclosure, safe (during decommissioning). A condition of a nuclear facility during the decommissioning process in which surveillance and maintenance of the facility take place.

identification. A process for recognizing a person or thing by a system.

indexing. Process of establishing access points to facilitate retrieval or records and/or information.

information. Data organized or processed in order to serve a purpose.

information management. A continuous cycle of five closely related activities: identification of information needs, acquisition and creation of information, organization and storage of information, information dissemination, and information use.

institutional control. Control of a radioactive waste site by an authority or institution designated under the laws of a State. This control may be active (monitoring, surveillance, remedial work) or passive (land use control) and may be a factor in the design of a nuclear facility (e.g. near surface repository).*

integrity. Integrity ensures that there is no unauthorized alteration to information and that the information is genuine and produced by the source as claimed. This includes the protection of information and information processing methods, such as applications, systems and networks, from intentional or accidental changes or impersonation. In brief, it is the absence of corruption or modifications.

knowledge. Information that is transformed through reasoning and reflection into beliefs, concepts and mental models.

knowledge management. An integrated, systematic approach to identifying, managing and sharing an organization's knowledge and enabling groups of people to create new knowledge collectively to help achieve the organization's objectives.*

metadata. Information about a particular data set which may describe, for example, how, when and by whom it was received, created, accessed, and/or modified and how it is formatted. This information can help to establish the record in its business context. Authoritative records are those accompanied by metadata defining their critical characteristics.

migration. Act of moving records from one system to another, while maintaining the authenticity, integrity, reliability and usability of the records.

nuclear facility (also facility or installation). A facility (including associated buildings and equipment) in which nuclear material is produced, processed, used, handled, stored or disposed of.*

operating organization (operator). The organization (and its contractors) which undertakes the siting, design, construction, commissioning and/or operation of a nuclear facility.*

operation. All activities performed to achieve the purpose for which an authorized facility was constructed.*

preservation. Processes and operations involved in ensuring the technical and intellectual survival of authentic records through time.

provenance. The origin or source from which something comes, and the history of subsequent owners (also known as the 'chain of custody' in some fields). The term is often used in the sense of place and time of manufacture, production or discovery. Comparative techniques, expert opinion, written and verbal records, and the results of tests are often used to help establish provenance.

quality assurance. The function of a management system that provides confidence that specified requirements will be fulfilled.*

records. Information created, received and maintained as evidence and information collected by an organization or person, in pursuance of legal obligations or in the transaction of business.

records management. The field of management responsible for the efficient and systematic control of the creation, receipt, maintenance, use and disposition of records, including processes for capturing and maintaining evidence of and information about business activities and transactions in the form of records.

records management system (RMS). A methodology or organized set of processes, procedures and tools for collecting, coding, compiling and storing (archiving) information and records to assure their proper management and future retrieval.

regulatory body. An authority or a system of authorities designated by the government of a State as having legal authority for conducting the regulatory process, including issuing authorizations, and thereby regulating nuclear, radiation, radioactive waste and transport safety.

traceability. Maintenance of changes, versions and revisions of a document that demonstrate the source and content of each evolution of the document.

transfer. Moving records from one location to another.

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This report draws on the growing body of experience (both positive and negative) related to the preservation of documentation and the retention of essential skills required to successfully plan and carry out decommissioning activities. In selecting and organizing 'lessons learned', the report provides a timely reminder, to decision makers and practitioners alike, that a lack of attention to record keeping may result in a costly misallocation of resources and may present safety problems. The report focuses on the management and organization of such records.

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