EDITORIAL NOTE

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Annex I

NATIONAL PROJECTS

The examples provided in this annex cover the organization of decommissioning and detailed technical aspects in both large and small facilities being decommissioned in a multifacility site. The descriptions will ideally be useful to provide practical guidance on how such decommissioning projects are planned and managed in various Member States. The examples given are not necessarily best practices. Rather, they reflect a wide variety of national and corporate legislation and policies, social and economic conditions, nuclear programmes and traditions. Although the information presented is not intended to be exhaustive, the information presented in this annex can be evaluated for its applicability to a specific decommissioning project. These annexes reflect the experience and views of their contributors and, although generally consistent with the main text, are not intended as specific guidance. These annexes have only been edited to the extent considered necessary for the reader's assistance.

I–1. ARGONNE NATIONAL LABORATORY: HOW DECOMMISSIONING EXPERIENCE TURNED ANL INTO A WORLD CLASS TRAINING CENTRE, USA

I–1.1 Experience base

The Argonne Nuclear Engineering Division, through its Decontamination and Decommissioning (D&D) Projects Group, has been leading and supporting the decommissioning of nuclear facilities at Argonne and at various other locations in the USA and abroad for over 30 years. The knowledge gained and the lessons learned from this work were applied to subsequent projects and shared with others. Some hands-on decommissioning work was performed using Argonne's in-house labour force while other projects were performed with contractors. Several projects required a coordinated effort by both forces. Other efforts focused on analysis of strategies and general planning support. The following areas of expertise are offered by D&D Projects Group:

- Project management and execution including cost, schedule, quality and technical baseline management;
- 'Path forward' planning, development, preparation and review (decommissioning plan, radiation protection, characterization plan, health and safety, QA plan);
- Project readiness reviews and facility walk-downs;
- Project health physics and industrial safety oversight;
- NRC licensing activities;
- Licence termination process;
- QA audits and assessments;
- Decommissioning training.

I–1.2. Operations and training

Operations is charged with cleaning up contaminated facilities at the Laboratory that are no longer needed. This work involves disassembling the components of the facility and then recycling or packaging them as waste, which is sent off-site for disposal. The facility is decontaminated and either released for reuse or demolished.

The role of the training element is to provide general D&D training courses or niche training to those with special needs. The courses are organized and planned by Nuclear Engineering Division personnel. Training is by Argonne instructors, as well as instructors drawn from other DOE sites, DOE, NRC, and commercial firms. They have presented over 50 courses since September 1997. Special courses have been presented for the IAEA, JAERI of Japan, CNEA of Argentina, NASA, and the US DOE-Princeton Plasma Physics Laboratory.

I–1.3. Decommissioning projects

As mentioned above, Argonne D&D Operations began establishing their own experience/expertise by tackling home projects. These covered a wide variety of different decommissioning activities from small scale projects such as smaller laboratory or lesser budgeted projects to large scale projects with larger facility footprints and funding to implement such as reactor decommissioning. A selection of projects is given in the following:

- Decontamination and decommissioning of the Experimental Boiling Water Reactor began in 1986 and was completed in February 1996 under DOE Argonne direction at a total cost of $19.5 million.
- The D&D of the ANL Chicago Pile-Five (CP-5) facility was initiated in 1991 and completed in July 2000.
- The decontamination and dismantlement of the JANUS Biological Reactor Facility at ANL was completed in October 1997.
- The D&D of the Argonne Thermal Source Reactor at ANL was completed in October 1998.
- The decommissioning of 61 plutonium glove boxes in nine laboratories located in Building 212 Plutonium Gloveboxes of ANL started in 1992 and was completed in 1996.
- The D&D of the ANL 60-Inch Cyclotron Facility began in 1997 and was completed in 2001.
- The purpose of ANL Building 200 M-Wing Hot Cells Decontamination Project was to eliminate the radioactive emissions of ^{220}Rn to the environment and to restore the hot cells to an empty restricted use condition (safe storage).
- The Experimental Breeder Reactor-II was shut down in late 1994 after 30 years of successful operation. The detailed Safe Storage Work Plan describing the final condition of the Experimental Breeder Reactor-II was implemented in October 2000.
- The Argonne D&D group has been managing numerous smaller scale D&D projects, including decommissioning of a 5000 sq ft kennel facility, multiple glovebox facilities, and plutonium contaminated equipment.

I–1.4. Decommissioning technologies

The ANL D&D Program is an integrated effort focused on addressing all technical facets of the D&D problem. The extensive operations and project execution experience of the Argonne D&D staff, coupled with ANL’s strong foundation in R&D, provides a uniquely integrated approach to identifying and overcoming the issues arising from a burgeoning D&D marketplace. Through its comprehensive field experience, ANL has developed unique insight and understanding into the critical role technology plays in project execution and in overcoming barriers to success encountered by using new and innovative techniques for solving D&D problems. The technology portion of the Argonne D&D Program comprises four major areas:

— **Identification:** Knowledge of and experience with the technologies and methodologies currently available for performing D&D is crucial to having a clear understanding of how best to perform D&D activities. This knowledge base is integral to determining the applications and limitations of current technologies, as well as effectively allocating limited R&D funding. Through its proven abilities in information management and distribution through multiple mechanisms, ANL serves as a conduit through which this information flows.
— **Development:** If, through the identification process, there are needs that cannot be met with existing technologies or there are suitable technologies that could be used with certain modifications and improvements, Argonne's extensive capabilities in scientific and technological problem solving can be brought to bear on the problem.
— **Demonstration:** The tightly regulated and monitored environment in which the nuclear industry operates presents unique challenges for the utilization of innovative or improved technologies. To be used in this highly regimented environment, it is critical that new and innovative technologies are processed through a robust, independent, and industry accepted and recognized demonstration process. ANL has a proven record in this area as shown by its participation in the CP-5 Large Scale Demonstration Project.
— **Deployment:** To ensure that the most effective technologies are utilized by the D&D user community, a vigorous technology information sharing system is critical. A thorough understanding of the limitations of D&D technologies in the marketplace is a crucial aspect of the deployment issue. ANL's experience in the entire spectrum of technology deployment is invaluable to ensure that innovative technologies are deployed in the most effective manner.

I–1.5. CP-5 Large Scale Demonstration Project

In 1996, ANL teamed with 3M, Duke Engineering & Services, ICF Kaiser, Commonwealth Edison and Florida International University to form the Strategic Alliance for Environmental Restoration. Under the sponsorship of the DOE, the mission of the Strategic Alliance is to select and demonstrate innovative D&D technologies.

The D&D needs of the DOE complex were evaluated, and the problem areas appropriate to demonstration at CP-5 were grouped into four areas: characterization, decontamination, robotics/dismantlement, worker health and safety. Twenty-three technologies were demonstrated at the CP-5 Reactor as part of the DOE EM-50 funded large scale demonstration project; a complete listing with vendor acknowledgments is provided below.

Characterization

— Field-Transportable Beta Counter-Spectrometer, developed by ANL and Triangle Research Ltd.;
— GammaCam™ Radiation Imaging System, developed by AIL Systems, Inc.;
— In Situ Object Characterization System, supplied by Canberra Industries, Inc.;
— Mobile Automated Characterization System, developed by Oak Ridge National Laboratory and the Savannah River Technology Center for the U.S. Department of Energy's Robotics Technology Development Program;
— Pipe Crawler Radiological Surveying System, developed by Radiological Services, Inc.;
— Pipe Explorer System™, developed by Science & Engineering Associates, Inc.;
— Portable X Ray Fluorescence Detector, supplied by TN Spectrace;
— Surface Contamination Monitor and Survey Information Management System, supplied by SRA, Inc.

Decontamination

— Advanced Recyclable Media System (ARMS™), provided by Surface Technology Systems, Inc.
— Centrifugal Shot Blast, provided by Concrete Cleaning, Inc.
— Empore™ Membrane Separation Cartridge, developed and provided by 3M.
— MOOSE® Remotely Operated Scabbler, supplied by Pentek, Inc.
— Pegasus Coating Removal System (PCRS), developed by Pegasus International, Inc.
— Rotary Peening with Captive Shot, provided by 3M Company and EDCO.
— Roto-Peen Scaler, supplied by Pentek, Inc.
— Starboldt™ Flashlamp System, supplied by Polygon Industry.

Robotics/dismantlement

— Dual Arm Work Platform, provided by a consortium of national laboratories and industry manufacturers. Individual components and subassemblies were purchased from or provided by Schilling Robotics Systems, Redzone Robotics, Inc., Oak Ridge National Laboratory, the Idaho National Environmental and Engineering Laboratory and Sandia National Laboratories.
— Remote Controlled Concrete Demolition System, manufactured by Holmhed Systems AB of Sweden and supplied by Duane Equipment Corp.
— Rosie Mobile Robot Work System, supplied by RedZone Robotics, Inc.
— Swing-Reduced Control and Remote Crane Operation Upgrades, supplied by Convolve, Inc. Installation and upgrades were funded by DOE's Robotics Technology Development Program.

Worker health and safety

— FRHAM-TEX Anti Contamination Suit, supplied by FRHAM Safety Products.
— NuFab Anti-Contamination Suit, supplied by the G/O Corporation.

I–2. DECOMMISSIONING OF AECL WHITESHELL LABORATORIES, CANADA

AECL Whiteshell Laboratories (WL) is a nuclear research and test establishment that has been in operation since the early 1960s. In the late 1990s, AECL began to consolidate R&D activities at CRL and began preparations for decommissioning WL. The facility occupies 4400 ha of land and employed more than 1000 staff up to the mid-1990s. Nuclear R&D programmes carried out at WL during the more than 40 years of operating history included the 60 MW WR1 organic liquid cooled research reactor, shielded facilities, materials science, post-irradiation examination, reactor safety research, small reactor development, chemistry, biophysics and radiation applications. The waste management area and inactive landfill are located approximately 3 km and 4 km, respectively from the main site. In preparation for decommissioning, a comprehensive environmental assessment was completed and the Canadian Nuclear Safety Commission subsequently issued a decommissioning licence for WL starting in 2003 — the first decommissioning licence issued for a Nuclear Research and Test Establishment in Canada.

The WL Decommissioning Project scope encompasses all the site buildings, facilities, land and infrastructure associated with the WL site. Initially, the project is focused on decontaminating and modifying nuclear facilities, laboratories and the associated service systems and removing redundant buildings to reduce risk and operating costs. The design, construction and operation of enabling facilities are fully under way. Site utilities are being decommissioned and reconfigured to reduce site operating costs.

New waste handling and waste clearance facilities have been constructed, and two new waste storage facilities have been constructed — a large shielded modular above ground storage for low level solid radioactive waste, and a soil storage compound for low level contaminated soil.

I–2.1. Decommissioning progress

The B300 Radiochemical Laboratory was the primary research laboratory. Comprising an area of approximately 17 000 m^2, the B300 complex housed over 170 laboratories, including a variety of radiological and non-radiological laboratories, approximately 400 offices, mechanical rooms and storage offices, and a high bay for large scale engineering experiments. B300 also includes shielded facilities and RD-14M Thermo-hydraulics Experimental Facility. B300 was constructed in seven stages and the strategy is to demolish the building similarly, in stages.

Prior to the NLLP funding the Van de Graaff Accelerator and Neutron Generator in B300 were fully decommissioned. During the five year initial NLLP funding, most of the equipment and services from the other areas in these three stages were removed, and the building is being decontaminated to an eventual free-release state, ready for demolition. The active drain lines, redundant furnishings, services, and active ventilation devices (e.g. fume hoods, glove boxes) from these areas have been removed. Nuclear research equipment has been removed and dismantled (e.g. thorium-nitric acid solution storage tank and piping).

With this work complete, the active ventilation system (e.g. ducting, fan system) is now being decommissioned. Work has started in one of the above three stages — this ventilation system is the least contaminated of all the B300 ventilation and is being used to gain experience prior to working on more contaminated systems.

Planning and design are also in progress for the remediation of soils in the crawl space. This work focuses on the reduction of cost and liability at the WL site. In particular, removal of the active ventilation system eliminates a potentially mobile source of contamination and eliminates the majority of the site heating demand, thus enabling early decommissioning of the costly central oil fired heating system. The remaining non-redundant buildings are being converted to less expensive and much cleaner electrical heating systems.

The shielded facilities include a 1200 m^2 hot cell facility (HCF), and a 1300 m^2 immobilized fuel test facility (IFTF), together with associated systems and operating areas. Six of the 12 Hot Cells were previously partially decommissioned. The other six hot cells have been decontaminated and are presently in a defined interim end state as they share active drain and ventilation systems with operating hot cells.

Associated experimental equipment such as a scanning electron microscope and hot cell 12 (which contained a metallographic microscope) were dismantled and removed.

The HCF storage blocks, which were used to store irradiated samples of reactor fuel and other radioactive samples prior to, and following, post-irradiation examinations in the HCF, have been decontaminated and are presently in a defined interim end state. Final decommissioning of the hot cells will follow the final decommissioning of the WR-1 reactor (Fig. I–1).

FIG. I–1. Dismantling of tank on top of the stack, WR-1 reactor, Canada (courtesy of WL).

Seven canisters in the IFTF, constructed of reinforced concrete 2.06 m diameter by 1.68 m height with an internal cavity of 0.65 m diameter and 1.44 m deep that were previously used to conduct a wide range of experiments in support of the Canadian Nuclear Fuel Waste Management Program, were dismantled and removed. Decommissioning of the IFTF's Warm Cells 14-18 is complete and included dismantling of the Warm Cells (main floor), and removal of the active ventilation and drain lines in the crawl space below the cells.

The cells were decommissioned in stages, starting with all exterior services, then the manipulators, interior services and decontamination (including cutting the cell liner), p-trap removal, window removal, lead brick removal, liner removal, and finally the table frames. Thereafter, the active ventilation and drain lines beneath the warm cells, located in the crawl space, were decommissioned. Cells 17 and 18 were the most contaminated, and lessons learned from Cells 14–16 were incorporated in their decommissioning.

Decommissioning activities in the shielded facilities, as with B300, reduced the nuclear liabilities of the WL site, and provides valuable floor space for new waste handling and treatment facilities that are needed for decommissioning. The warm cells are smaller and have less shielding than the hot cells. They were also used in support of the Canadian Nuclear Fuel Waste Management Program, where a wide range of experiments using radioactive material was carried out.

Plans are under way for the decommissioning of two other nuclear buildings at WL — the active liquid waste treatment centre and the laundry and decontamination centre (B411). The functions of these two buildings are being reconfigured and consolidated in the shielded facilities and B300.

The ALWTC began operation in 1963, receiving low level liquid waste effluent from site operating nuclear facilities. The liquid effluents are transferred via underground lines connecting operational facilities to the ALWTC for temporary storage in holding tanks prior to sampling, treatment and controlled release. The facility includes an intermediate level liquid waste processing system, taken out of service in 2001, which concentrated liquid waste originating from the shielded facilities and the WMA. The concentrate was solidified and then transferred to the WMA for storage.

The laundry and decontamination centre have been in operation since 1966, providing laundry service for radioactively contaminated clothing, and decontamination services for maintaining R&D rigs, equipment and tools in a safe usable state.

Several other smaller buildings have also been decommissioned (some were removed for reuse, others were demolished while maximizing material that could be recycled). These buildings were the Internal Friction Laboratory buildings (B500 and B530), the Gas Dynamics Facilities (B307 trailer and grain bin, B312), the Drill Site Office trailer (B515), the Meteorology Trailer #2 trailer (B525), and the Engineering Development and Civil Storage buildings (B504, B509, B526).

I–3. DECOMMISSIONING THE BOHUNICE V1 NPP, SLOVAKIA

A.1. I–3.1. Objectives and scope of decommissioning

In 1999, Slovakia committed to shut down of Units 1 and 2 of the Jaslovské Bohunice V1 NPP (V1 NPP, see Fig. I–2) by the end of 2006 and 2008, respectively, adopting Government Resolution No. 801/1999 dated 14 September 1999, in compliance with the Energy Policy of the Slovak Republic. Both units were shut down on schedule.

FIG. I–2. Jaslovske Bohunice NPP (photo courtesy of JAVYS, a.s.).

As of 20 July 2011, the operation phase of V1 NPP officially ended and the power plant entered the decommissioning phase following the Decision of Regulator (Nuclear Regulatory Authority of the Slovak Republic (ÚJD SR)) ‘the licence for the 1st stage of V1 nuclear power plant decommissioning of Unit 1 and 2’.

The ‘immediate dismantling option’ was selected and approved by the management of JAVYS, a.s., and Ministry of Environment of the Slovak Republic pursuant to the V1 NPP Conceptual Decommissioning Plan. The main features of this option are immediate and continuous dismantling of the equipment, the demolition of buildings down to the bottom of the foundation pit and the preparation of the area to make it available for further use.

The final site status will be brownfield/restricted use. This term means a real property, redevelopment, or reuse of which may be complicated by the presence or potential presence of a hazardous substance, pollutant, or radioactive contamination. In potential redevelopment plans for the site (use for other industrial or nuclear purposes) will need to consider whether site remediation can achieve end points that are compatible with their intended reuse.

The decommissioning of Bohunice V1 NPP will be performed in two stages (with a final deadline in 2025) in addition to the pre-decommissioning activities which have been carried out prior to the decommissioning itself.

The pre-decommissioning activities included the total defuelling of the reactors into the respective spent fuel pools and consequently into the on-site independent interim spent fuel storage facility, preparation of waste processing facilities, conditioning the historical wastes, plant physical and radiological characterization, modifications to electrical and mechanical systems and their tag-outs to allow start-up of the dismantling operations, access control and physical security. During this stage, technical studies, technical specifications and tender dossiers for contracting the Stage I projects were performed.

Stage I activities encompass the removal of non-active systems and demolishing of structures no longer needed. This includes the removal of systems from the turbine building, demolishing of structures such as buildings associated with the cooling function, partial dismantling of electrical outdoor equipment and switchgears, removal of systems and demolition of the diesel generator building, dismantling of some outdoor tanks and the preparation of buffer waste storage places onsite and primary circuit decontamination. During this stage, technical and procurement documentation is being prepared to contract the Stage II projects and some conditioning of the buildings for future use will also be performed.

Stage II activities cover the removal of the remaining plant systems and demolishing of remaining structures within the decommissioning scope. This includes the removal of systems and components from the reactor building, the auxiliary building, and the cross side and lengthwise electrical buildings. Outdoor tanks and buried piping trenches and cables will also be dismantled/demolished. Building decontamination and demolition will be performed once the systems are dismantled. Site release from the regulatory control of UJD SR will be applied for after site restoration (or cleanup) and Final Site Survey as licence termination activities.

The scope of the decommissioning considered is limited to the Bohunice V1 NPP structures, systems and components which are not shared with other facilities. Therefore, the Interim Spent Fuel Storage Facility, the Bohunice Radwaste Treatment Centre, the Auxiliary Boiler will be kept untouched. In addition, a new building for the temporary storage of special wastes not acceptable at the National Radioactive Waste Repository (NRR) in Mochovce will also remain untouched after V1 NPP decommissioning. A significant number of shared storage buildings and workshops are found on the plant site. Some of them will be used as buffer storages for the decommissioning materials.

Managing the historical waste and the decommissioning waste is a package of activities which has been carefully programmed throughout the duration of the decommissioning process. This includes the treatment and conditioning of the wastes produced during the plant operation, namely solids, metals, sludges and sorbents. Upgrading of the existing radwaste treatment facility began and new projects have been defined for the treatment of sludges and sorbents and for the fragmentation and decontamination of existing and future V1 NPP decommissioning wastes. The enlargement of the Mochovce repository to provide it with enough capacity to handle disposal of low level decommissioning waste and the construction of a new very low level waste facility are also considered here. Activities of the material free release are also considered important to minimize the volume of wastes to be sent to NRR Mochovce and thus significantly decrease their disposal cost. The time frame for the entire period of V1 NPP decommissioning is shown in Fig. I–3:

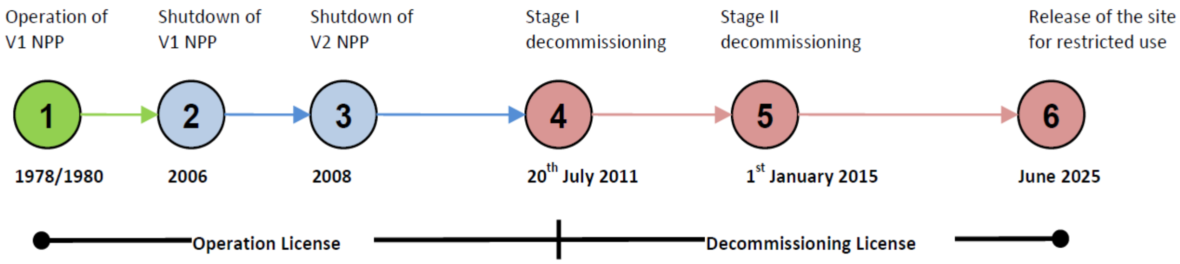


FIG. I–3. Bohunice V1 NPP decommissioning time frame (courtesy of JAVYS, a.s.).

I–3.2. Status at the beginning of the first stage of decommissioning

After the final shutdown of reactors the radiological situation of the V1 has been characterized. The total activity recorded represents the value of 2.03E+17 Bq with 2.43E+08 kg total mass of equipment which is the sum of activation and contamination:

— The total inventory of activated reactor parts and adjacent civil structures was determined at the level of 2.03E+17 Bq as the combination of its physical and radiological parameters. This induced activity corresponds to the total mass of 1.39E+06 kg materials. Induced activity of reactor internals represents up to 99.7% of the total activity;
— Total inventory of contaminated equipment and civil structures was determined at the level of 1.18E+13 Bq. This contamination value corresponds to the total mass of 2.41E+08 kg materials.

The average concentration for contaminated civil structures is 0.2 Bq/g and the average concentration for contaminated equipment is around 1 kBq/g. The first value indicates the feasibility of the free release option for civil structures while sorting and decontamination will be necessary for contaminated equipment.

The main aspects of physical status at the beginning of the decommissioning were as follows:

— Spent nuclear fuel of Units 1 and 2 is removed from the reactor building and transported to the interim spent nuclear fuel storage;
— Remaining quantity of operational radwaste is processed, except concentrates in the Auxiliary Building (approximately 660 m^2), highly contaminated or activated solid radwaste (approximately 40 t), and possibly other historical solid radwaste;
— The primary circuit is filled with demineralized water at atmospheric conditions. Other operational media were removed.

I–3.3. Radwaste management facilities at Bohunice

The following technologies for treatment and conditioning of radwaste are being used by JAVYS, a.s. at the Bohunice site.

Bituminization facility. This is used for treatment of radioactive concentrates into drums. A new technological facility (discontinuous bituminization line) for treatment of radioactive sorbents and sludge has been installed as a part of the non-functional plant for resin and sludge calcinations.

Purification station of radioactive water. Water contaminated chemically and radio-chemically is cleaned by evaporation in a boiler evaporator equipped with an external heater. The resulting condensate is cleaned by ion exchangers until the specific activity of radionuclides in condensate drops below the limit values.

The Bohunice Radwaste Treatment Centre, which was commissioned in 1999 and licensed at the beginning of 2001. The facility includes:

- Incineration plant (incineration of combustible liquid and solid radwaste);
- High pressure compacting facility (compacting of solid radwaste, in particular metal waste);
- Concentration facility (final evaporation of concentrates on the evaporator);
- Facility for radwaste conditioning by cementation to fibre–concrete containers (FCCs);
- Sorting facility for sorting of solid radwaste;
- Storage and transportation facility.

Decontamination facilities (chemical, electrochemical and ultrasonic technologies) for metallic wastes consisting of decontamination baths, storage tanks and the auxiliary systems.

The NRR at Mochovce is a near surface repository designed to dispose of radwaste resulting from the operation and decommissioning of other nuclear facilities. It serves and will serve for the disposal of low level and very low level radwaste of all Slovak NPPs (i.e. V2 NPP and NPP Mochovce) and decommissioning of nuclear facilities (i.e. A1 NPP and V1 NPP) and from research institutes, laboratories, hospitals and other institutions (the institutional radwaste mentioned above).

All wastes meeting acceptance criteria for disposal at the NRR, independent of their activity level, are at the present time packaged in FCCs, with an effective volume of 3.1 m^3 and an ‘occupied’ volume of 5 m^3. The existing disposal facility consists of two double rows of reinforced concrete vaults. The dimensions of a vault are 17.4 m × 5.4 m × 5.5 m, with an effective volume of 510 m^3. Each row includes 20 vaults divided into five expansion units containing four vaults each. Each vault is able to house 90 FCCs. The capacity of the two existing double rows is thus amounts to 7200 FCCs. Currently, FCCs are disposed of at the second double row.

In addition there are variety of fragmentation, transportation and decontamination equipment available as well as a new metallic radwaste melting facility (from 2019) and interim storage as a waste and material buffer capacity before further processing.

I–3.4. Status of the systems and buildings at the end of decommissioning Stage I

Decommissioning Stage I projects encompass the removal of non-active systems and demolishing of structures no longer needed for Stage II dismantling. These projects are included into ’D’ projects category. These include the removal of systems from the turbine building, demolishing of some structures and buildings associated with the cooling function, partial dismantling of electrical outdoor equipment and switchgear, removal of systems from and demolition of the diesel generator building, dismantling of some outdoor tanks and the preparation of buffer waste storage areas on-site.

A brief description of the V1 NPP at the end of Decommissioning Stage I is given below:

- Unnecessary non-radioactive buildings with equipment of secondary circuit were decommissioned, including cooling towers (Fig. I–4).

— Unusable technological equipment is dismantled in those buildings, which were included into the scope of Stage I.
— Demolition of the non-radioactive unnecessary buildings is completed.
— Some non-radiologically contaminated buildings (turbine hall, buildings with auxiliary electrical systems — longwise side and cross-side electrical building) were not demolished after dismantling a substantial part of their technological equipment and their decommissioning was shifted to the next period.
— Technological equipment in buildings with systems in operation (reactor building, auxiliary building and others) has remained untouched.
— Remaining part of non-radioactive buildings is not the subject of dismantling and demolition (technology and building part). This part is divided into group of buildings to be decommissioned in Stage II and group of remaining buildings.
— Non-contaminated waste (even radwaste, if generated), is finally transported to dumps and repositories.
— Part of the site, in which buildings are to be removed (demolished) during the decommissioning Stage I, is subject to earthworks according to the Site Clean-up Plan.

FIG. I–4. Demolition of the V1 NPP's four cooling towers. Note the operational cooling towers of the V2 NPP (photo courtesy of JAVYS, a.s.).

I–3.5. Expected status at the end of Decommissioning Stage II

The aim of the Stage II (2015–2025) is the decommissioning of structures and buildings in the nuclear island, i.e. the reactor, steam generators, main reactor building, auxiliary operations building and remaining auxiliary buildings, which have not been decommissioned in Stage I of the decommissioning process.

The main activities in the second stage of the decommissioning the V1 NPP are the following:

— Preparation and dismantling of reactors of Units 1 and 2;
— Preparation and dismantling of the primary circuit equipment (see Figs I–5 and I–6);
— Dismantling of other equipment in the controlled area;

- Removal of contamination from buildings and subsequent radiation monitoring of cleanliness of systems and buildings;
- Demolition of original buildings down to their foundation slab;
- Site restoration and its release from under the administration of the Atomic Act with subsequent release into environment for unrestricted industrial use.

The above mentioned activities will be consistently managed and supported by activities, such as project management, technical support, supporting systems operation, radiation protection, maintenance, industrial and radiation safety and other.

From the technical point of view, the most challenging activities in the second stage of decommissioning will include intended dismantling of reactors and dismantling of related equipment of the reactor coolant system, which apart from special radiation characteristics, may be considered to be technological challenge regarding their manipulation, since they are focused on dismantling of large components with weight exceeding 100 t. Also, due to this, selection of the optimal alternative of the reactor dismantling was made after the special study has been drafted. This study defined detailed proposals of procedures/sequences for individual alternatives of dismantling, including their safety and economic characteristics.

FIG. I–5. Transport of the steam generator for fragmentation in the turbine hall (photo courtesy of JAVYS, a.s.).

FIG. I–6. Retrieval of the reactor pressure vessel (photo courtesy of JAVYS, a.s.).

Brownfield/restricted use will be the site's final status at the end of the Stage II. This status will be achieved after successful completion of the final radiological survey. This survey, to be done at the end of the decommissioning, will release the site from regulatory control after demonstration of compliance with the authorized regulatory clearance levels for restricted use of the V1 NPP site.

Demolition of civil buildings will be performed down to the bottom of the construction pit. The radiation monitoring will be performed in the area remaining after decommissioned buildings that will verify that the area can be released for restricted use. Consequently, the site will be filled with backfilling materials and backfilled, compacting and final landscaping will be performed. The site will be prepared for handover to the user.

I–4. DECOMMISSIONING THE BOHUNICE A1 NPP, SLOVAKIA

The A1 NPP (Fig. I–7) was in operation from 1972 until shutdown in 1977 (after an accident); since 1980, it is in decommissioning status. The unit was an HWGCR (heavy water moderated gas cooled reactor) using natural uranium fuel, with total electrical power from the three generators of 150 MW(e).

FIG. I–7. The A1 NPP, Jaslovske Bohunice (photo courtesy of JAVYS, a.s.).

In the former Czechoslovakia, legislation specifying the framework for the nuclear facility decommissioning or technical conditions for implementation of such activities was not applicable. Apart from legislative and administrative conditions and staffing required for these activities, specific technological facilities for management of radwaste and spent nuclear fuel, including the repository for final disposal of radwaste and related transport means were being gradually designed and constructed.

Governmental Resolution No. 266/1993 dated 14 April 1993, requested "to prepare a comprehensive proposal to place NPP Bohunice A1 into the radiologically safe condition". According to the Atomic Act No. 541/2004 Coll., such activity is defined as 'Decommissioning of Nuclear Installation' and allows implementation in stages.

Work executed by 1994 was focused primarily on elimination of consequences of the operational events. Subsequently, pre-decommissioning activities were in progress by 1999. These activities included dismantling of several technological facilities, creation of areas required for installation of technological facilities intended for management of radioactive materials, decontamination of selected areas/premises, mainly in the main reactor building and transport of spent nuclear fuel used in the A1 NPP reactor outside Slovakia.

I–4.1. Decommissioning process

The objective of the Stage I of decommissioning was to secure a safe radiation state of the A1 NPP. Activities implemented in this stage addressed the following tasks: long term storage and removal of SNF, processing of liquid radwaste in external buildings, contaminated waters and technological facilities in the plant main reactor building. Preparation of future projects focusing on decontamination and removal of the primary circuit systems/equipment and also revision of priorities focused on extended monitoring of the heavy water and gas circuit reactor [I–1].

The activities of Stage II are focused on removal of environmental loads from the A1 external buildings, removal and sorting of contaminated soil and concrete debris and monitoring and treatment of underground and leaking water, treatment and conditioning of historical radwaste and radwaste from the A1 NPP decommissioning, decommissioning of technological equipment and civil units of external buildings and buildings of A1 main reactor building and decommissioning of long-term storage for spent nuclear fuel. Within the second stage, the disposal facility for very low level waste in the of NRR Mochovce nuclear facility is also to be built within the scope of first module erection and designated for disposal of very low level waste from the A1 NPP decommissioning.

Activities of Stage III and IV will be focused on the decommissioning of long term storage for A1 NPP nuclear spent fuel, processing of sludge from long term storage, casks of the long term storage of nuclear spent fuel and liquid radwaste from the external tanks of storage place for liquid radwaste, decommissioning of mutually connected technological parts, (steam generators with accessories, turbo compressors, section valves).

The subject of the final Stage V of A1 NPP decommissioning is the nuclear reactor itself and connected equipment in reactor shaft, short term storage, long term storage pool for spent nuclear fuel and equipment situated in Reactor Hall, which were installed and used for the decommissioning process itself. From the previous stages, decommissioning of the remaining steam generators with accessories will continue. Decommissioning such equipment produces radwaste which cannot be disposed of at the national repository for low level waste and will be stored in the Interim Storage of radwaste until the deep geological repository is built.

The operation and decommissioning stages of A1 NPP are shown in Fig. I–8.

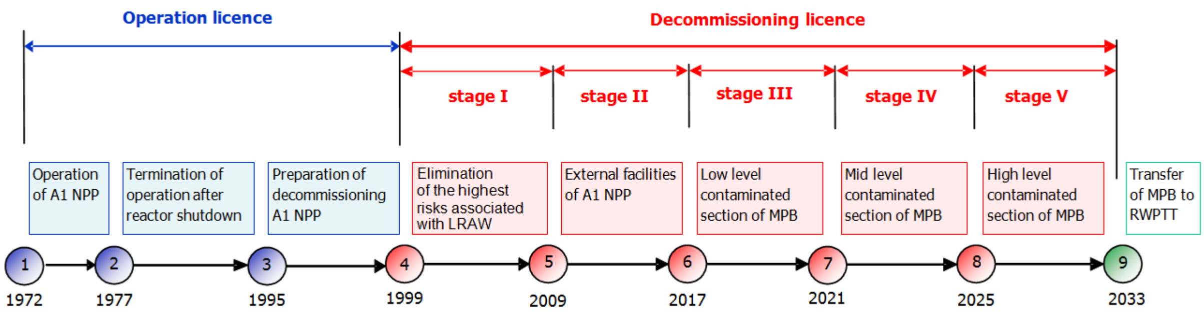


FIG. I–8. Operation and decommissioning stages of the A1 NPP (courtesy of JAVYS, a.s.).

The A1 NPP decommissioning process is continual and is a very complex and specific process. During its demanding implementation, safety is the main criterion of all activities, and therefore, in respect of nuclear safety and radiation protection, no substantial negative impact of such activities on the environment was recorded. Decommissioning works are implemented continually pursuant to the strategic document approved by the Slovak Government, 'The Proposal of National Policy and National Programme for Spent Fuel Management and Radioactive Waste in the Slovak Republic' as an update of the strategic document, 'The Strategy of Final Stage of Peaceful Use of Nuclear Energy in the Slovak Republic' in accordance with procedure of EC 2011/70/Euratom with an objective to fully free release the plant site for its further industrial use.

I–5. DECOMMISSIONING OF THE MULTIFACILITY CHORNOBYL NPP SITE, UKRAINE

According to the Memorandum of Understanding between the governments of G7 countries, the European Community and the Government of Ukraine, on Chernobyl NPP Shutdown dated 20 December 1995, Ukraine accepted the obligation of shutting down the Chornobyl NPP before 2000 and its subsequent decommissioning.

Demonstrating its commitment to these obligations, Ukraine has shut down all three operating Chornobyl NPP units for decommissioning before the design lifetime expiration. The last operating Unit 3 was shut down on 15 December 2000.

I–5.1. Integral decommissioning programme for the entire site versus separate programmes for each facility

Units 1 and 2 of Chornobyl NPP were built according to the same design and have the same structure, and common auxiliary premises. The radiation situation in similar premises of both units is approximately the same.

Therefore, the basic design solutions, content and sequence of decommissioning works performed at Units 1 and 2 are practically the same and will differ only in the time of their implementation. The impact on workers, the general public and environment will be similar and, accordingly, there will be similar safety measures for Unit 1 and 2 decommissioning.

Unit 3 has been built in accordance with another design and structurally is different from Units 1 and 2. It has common building constructions, as well as a number of technological systems, common with Unit 4 destroyed as a result of the accident (the 'Shelter' project, to recover from the accident, is further addressed in Section I–6).

The radiation situation in Unit 3 is significantly worse than in Units 1 and 2. Consequently, the design solutions and measures to safety assurance, carried out at Unit 3 will differ from Units 1 and 2. All work will ideally be coordinated with the work at the Shelter project.

In Ukraine it was decided to develop a unified decommissioning programme for the entire Chornobyl NPP site. Site decommissioning activity planning and management allowed the development of an optimal, interrelated schedule of decommissioning works (including work at the Shelter project).

In terms of licensing activity, the Chornobyl NPP site is considered as a single licensed nuclear installation. The State Nuclear Regulatory Committee of Ukraine issued the 'Licence to the State Specialized Enterprise Chornobyl NPP for Chornobyl NPP Decommissioning' in March 2002. Earlier, the 'Licence for Shelter Object Operation and Transformation into an Ecologically Safe System' was obtained in December 2001.

Currently, all three units are at the same level of readiness for decommissioning. The list of activities and range of planned activities is similar for them and differs only in terms of implementation. This makes it possible to spread successful organizational and technical solutions and technologies for all installations located at the site. This approach allows optimally sequential works and, in some cases, to organize their parallel execution. Eventually, this leads to cost savings and more efficient use of infrastructure and qualified personnel.

I–5.2. Chornobyl NPP Units 1–3 decommissioning strategy

The recent strategy for Chornobyl NPP decommissioning has been continuously improved and refined from the strategy set in the Concept 1992 to the strategy proposed in the Decommissioning Programme 2008. During these years the following was analysed and taken into account: results of various R&D work, international experience in decommissioning, IAEA recommendations, and comments of the Regulatory Body of Ukraine.

A 'deferred dismantling' strategy has been accepted for the Chornobyl NPP units. However, the term deferred dismantling relates only to the reactor and some systems adjacent to it, which have a high level of radiation contamination and dismantling of which is not possible at the early stage due to the lack of necessary infrastructure (final disposal facilities for long lived radwaste) and high collective doses.

The 'external' equipment with low contamination of Chornobyl NPP that is not subject to preservation will be dismantled by 2025, i.e. by the start of the safe enclosure stage. The Chornobyl NPP Units 1–3 decommissioning strategy has the following sequence of stages (see Fig. I–9):

- Shutdown: current, final stage of facility operation: the main task of the stage — release of power units from nuclear fuel. Completion date: 2015.
- Preparation for preservation (over 10–12 years, from 2015 to 2028).
- Safe enclosure (from 2028 to 2045).
- Dismantling (over 20 years, from 2045 to 2064).

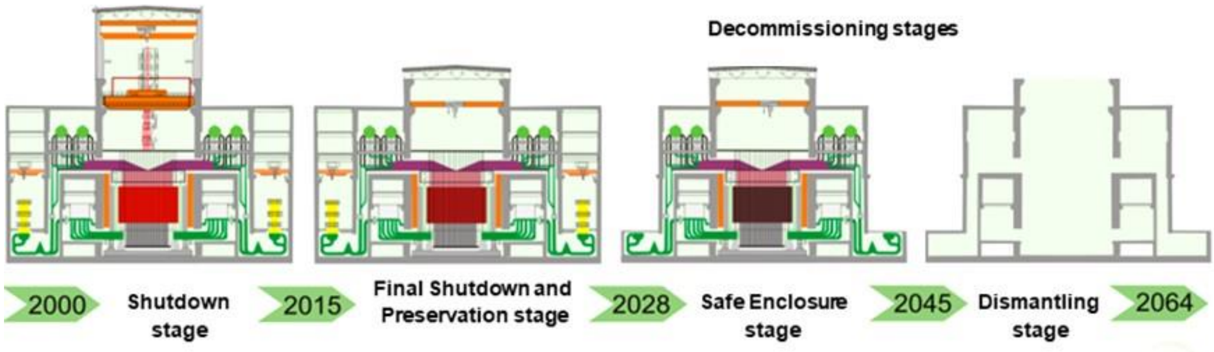


FIG. I–9. Chornobyl NPP decommissioning licence, stages and final states (courtesy of Chornobyl NPP).

The main objective of the final shutdown and preservation stage is to bring the Chornobyl NPP units into a state that excludes the possibility of their use for the purposes for which they were constructed. It complies with the safe storage of radioactive substances and ionizing radiation sources located inside them during a definite period of time.

At the stage of safe enclosure a nuclear facility is in the preserved state corresponding to the safe storage of ionizing radiation sources located inside it. The main objective of the stage is considerable reduction in the quantity of radioactive substances at a nuclear facility due to natural decay of radionuclides. Duration of the stage will be not less than 20 years, with expected start in 2028 and completion in 2045.

At the stage of final dismantling are ionizing radiation sources which are located in a nuclear facility, removed from the facility and placed into the radioactive waste storage facilities. The expected implementation period will be from 2045 to 2064. Further activities will include remediation which will be carried out within the framework of the Exclusion Zone remediation programme.

I–5.3. Final status of Chornobyl NPP decommissioning

It is not reasonable to proceed with decommissioning of the Chornobyl NPP up to ‘green field’ unrestricted conditions because the Chornobyl NPP is located within the Exclusion Zone contaminated by radioactive substances as a result of 1986 accident. Power Unit 3 has common building structures with the Shelter. Consideration also has to be given to the possibility that no new power and other national economy facilities can be built on-site.

The most preferable final status of the Chornobyl NPP decommissioning is such that it can be conditionally specified as a ‘brown spot’ site. In this regard, taking into account the Chornobyl NPP location within the 10 km Exclusion Zone, which is heavily contaminated with long lived radionuclides and a great number of buildings, the full dismantling of the buildings within the framework of Chornobyl NPP decommissioning is considered to be unreasonable. Such a task will ideally be resolved within the framework of a unified programme of Exclusion Zone remediation.

Thus, the final state during Chornobyl NPP decommissioning is dismantling of the equipment, which is not necessary for the SSE Chornobyl NPP activity, and cleaning/decontamination of building structures up to levels of restricted release from regulatory control.

I–5.4. Reuse of the Chornobyl NPP site

Since 1992, the strategy has been continuously evolving. Along with the strategy, various options for the final state have been reviewed. Normative documents of Ukraine established the main objective of decommissioning of non-accident nuclear power plants — reuse of the nuclear power plant territory.

Currently, the Chornobyl NPP decommissioning strategy determines the final state of the industrial site from the radiological point of view as a brown spot. From a practical point of view, taking into account the specificity of the Exclusion Zone, the optimal solution for the final status of Chornobyl site decommissioning is an industrially developed site integrated into the Nuclear Industrial Complex of Ukraine using the developed infrastructure and Chornobyl NPP staff.

In 2008, a new plan for the final state for Chornobyl NPP decommissioning prepared: an industrially developed area with the possibility to reuse the site (see Fig. I–10).

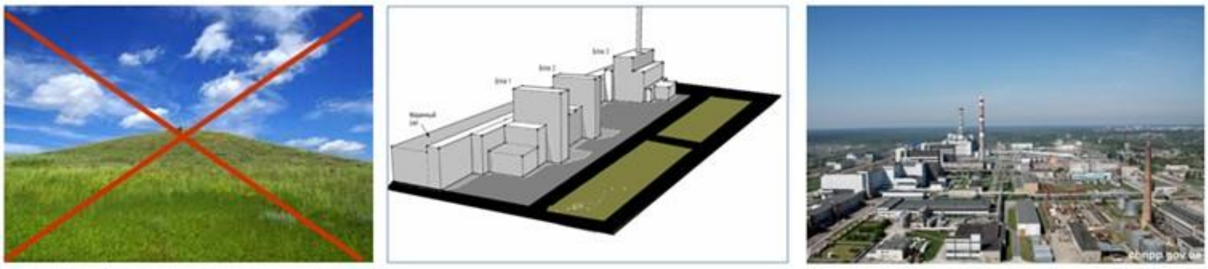


FIG. I–10. Evolution of the final status of the Chornobyl NPP — from green field through brown spot to an industrially developed site (photos courtesy of Chornobyl NPP).

The Chornobyl NPP site, Exclusion Zone and infrastructure are convenient for the creation of nuclear industries and technologies for radioactive waste and spent fuel processing and storage. This ensures the constructive use of the territory, buildings, construction and personnel in the economic activity of the country, remediation and development of the depressed region affected by the Chornobyl accident and its transformation into the prospective and economically developed site.

I–6. STRATEGY OF CHORNOBYL NPP UNIT 4 (SHELTER) TRANSFORMATION INTO AN ECOLOGICALLY SAFE SYSTEM, UKRAINE

On 26 April 1986, the worst accident in the history of nuclear energy occurred at Unit 4 of the Chornobyl NPP in the former Soviet Union. As a result of the accident, the reactor was completely destroyed (Fig. I–11), contaminating a vast area of about 200 000 km^2 and producing a large amount of high level radioactive waste at the destroyed unit and NPP site. Construction of the protective shelter above the emergency unit was started in May 1986 under severe radiation conditions.

FIG. I–11. Unit 4 of the Chornobyl NPP destroyed as a result of the accident (photo courtesy of Chornobyl NPP).

Later, in November 1986, the State Commission accepted for maintenance the preserved Unit 4, which was named ‘Shelter’ or ‘Sarcophagus’ (Fig. I–12). The Shelter or Sarcophagus represents the approach to limit the release of contamination following the beyond design basis accident at Unit 4 of Chornobyl NPP, which lost all functional properties of the power unit, and at which priority measures to reduce the accident consequences were performed and work is under way to ensure nuclear and radiation safety.

Within a very short time — just six months — the destroyed Unit 4 was transformed into the Shelter, which had no analogues in the world. This allowed mitigation, within the shortest time, of the negative impact of the destroyed unit on the environment, personnel and general public. The Chornobyl NPP accident emergency mitigation stage was completed: unprecedented in its scale, this human-made source of hazard was localized.

Simultaneously with construction of the Shelter, a large amount of work involving decontamination of the area around the Shelter as well as the roof of adjacent facilities inside the Chornobyl NPP premises was performed which allowed the undamaged Units 1–3 to go back into operation.

FIG. I–12. A general view of the Shelter (photo courtesy of Chornobyl NPP).

Further actions to transform the Shelter have been performed according to plan with the participation of the international community. According to the Strategy of the Shelter transformation approved by the Interdepartmental Commission on comprehensive solution of Chornobyl NPP of March 12th, 2001, conversion of the Shelter into an ecologically safe system is achieved in three basic stages (Fig. I–13).

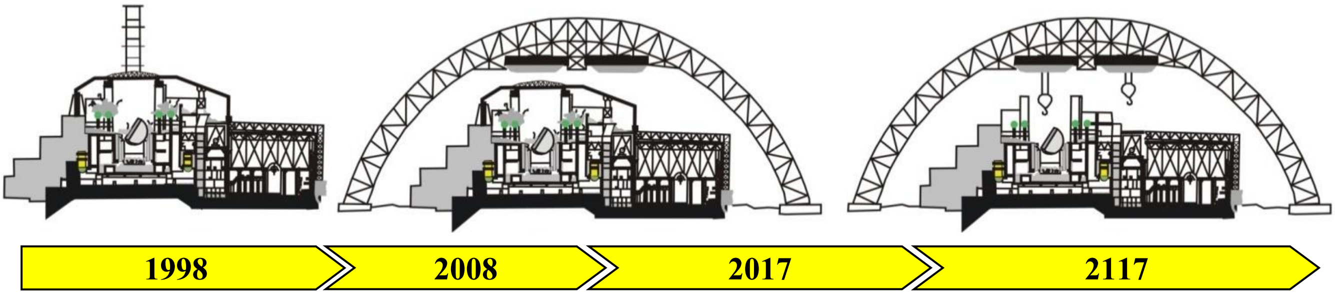


FIG. I–13. Strategy of the Shelter transformation into an ecologically safe system (photo courtesy of Chornobyl NPP).

I–6.1. Stage 1: Stabilization

A set of measures to improve the durability, reliability and efficiency of existing or additionally structures and systems (construction, control, dust suppression, emergency) needed for maintenance or improvement of the existing safety level at the facility was carried out during this stage (1998–2008). The objective of stabilization was to reduce the risk of collapse of the Shelter structures prior to completion of the new safe confinement (nsc). Implementation of stabilization measures allowed improvement of the safety level of the Shelter building until 2023 (Fig. I–14.). In future, the problem of unstable Shelter structures will be resolved by dismantling or reinforcing this construction inside the NSC.

FIG. I–14. View of the Shelter after implementation of stabilization measures (photo courtesy of Chornobyl NPP).

I–6.2. Stage 2: Creation of protective barriers (new safe confinement construction)

The construction of the NSC (2008–2018) was intended to achieve the following objectives:

- Ensuring protection of personnel, public and the environment against the influence of nuclear and radiation hazard sources associated with the Shelter;
- Creation of the necessary conditions for the performance of activities aimed at transformation of the Shelter into an ecologically safe system, including for retrieval of residues of nuclear fuel and FCM, radioactive waste management and unstable construction dismantling/reinforcement of the Shelter .

The NSC (Fig. I–15) is a protective structure, which includes a complex of technological equipment for the retrieval of nuclear fuel containing material from the destroyed Chornobyl Unit 4, radwaste management and other systems intended for transformation of this unit into an ecologically safe system for the safety of personnel, public and the environment.

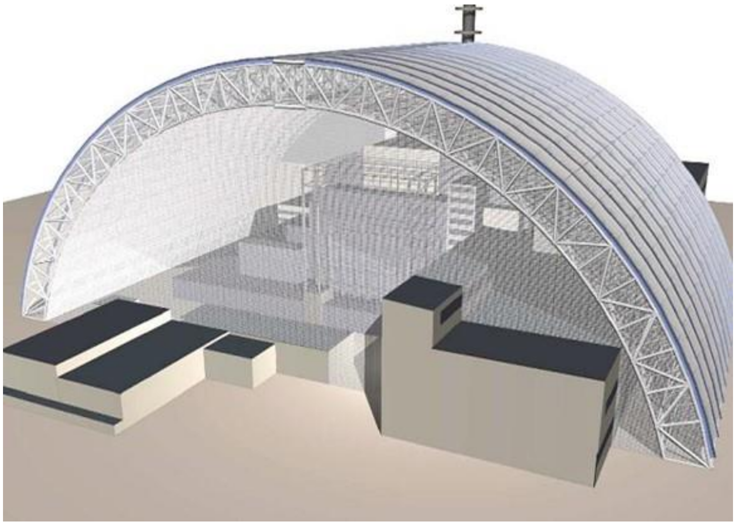


FIG. I–15. Design of the new protective structure — NSC (photo courtesy of Chornobyl NPP).

Design, construction and commissioning of the NSC is performed by the International Consortium NOVARKA consisting of two French companies: VINCI Construction Grands Projets and Bouygues Travaux Publics. The construction involves specialists from contractors and subcontractors from 27 different countries around the world. However, the bulk of the work is done by 2000 Ukrainian workers, of whom more than 1000 are constantly present on the Shelter site.

The lifetime of the NSC is 100 years. According to the design, the NSC includes: (a) main building consisting of arch structure that is 108 metres high, 162 metres long and has a span of 257 metres; (b) foundations, eastern and western end walls and necessary support systems; (c) technological building, including decontamination, fragmentation and packaging facilities, sanitary locks, workshops and other technological facilities; and (d) auxiliary facilities.

To ensure NSC’s nuclear, radiation and industrial safety and for its effective operation with involvement of a minimum number of operational personnel it was planned to create an NSC Integrated Management System which will consist of the following systems:

- Radiation safety monitoring system;
- Seismicity monitoring system;

- Building construction condition monitoring system;
- Operation support systems: ventilation, water supply; sewerage (including liquid radioactive waste management), power supply systems;
- Technological systems for radwaste and FCM management.

It is planned to create fire safety and nuclear security systems and to mount communication and television networks. To ensure dismantling of unstable structures it is planned to install crane equipment. The main functions of the NSC are to limit the radiation impact on population, personnel and environment within the established boundaries, both during normal operation of the Shelter and in case of normal operation disturbances, emergencies and accidents, including accidents in the process of dismantling unstable structures and future FCM and radwaste management.

The NSC is also intended to limit the spread of ionizing radiation and radioactive substances present inside the Shelter and provide technological support, i.e. creation of conditions for the dismantling of unstable structures, retrieval of future FCM and radwaste, removal of accumulated water, and ensure implementation of control and maintenance measures in the Shelter and at its industrial site. NSC provides physical protection, i.e. preventing unauthorized access to FCM and radwaste and maintaining the functioning of the IAEA safeguards system.

The NSC will help to achieve the following:

- Improve the radiation safety level. The integrity of the NSC's construction will restrict the radiation impact on the population, personnel and environment for a period of operation of 100 years.
- Reduce the probability of accidental collapse due to dismantling of unstable structures.
- Reduce the impact of emergency collapse using protective and load bearing structures and monitoring systems inside the NSC.
- Improve the Shelter's nuclear safety by eliminating penetration of atmospheric moisture in FCM that significantly reduces the risk of a self-sustaining chain reaction.
- Ensure implementation of the Strategy of Shelter transformation into an environmentally safe system due to the durability of NSC structures, feasibility of the existing Shelter, dismantling of unstable structures and retrieval of FCM.

The NSC was placed in November 2016 and thus the successful enclosure of the heavily damaged Unit 4 at Chornobyl was formally completed (Fig. I–16). Installation of technological equipment is being performed. NSC commissioning started in 2018.

FIG. I–16. Placement of the NSC (photo courtesy of Chornobyl NPP).

I–6.3. Stage 3: Shelter transformation into an ecologically safe system

Within the third stage, according to the Strategy, it is planned to remove FCMs from the Shelter (if there are no alternative options for transforming FCMs to the controlled state) to transform them into a controlled state by providing controlled storage within the protective barriers and/or disposal in geological radwaste disposal facilities. Thus, all FCMs will ideally be sorted according to activity level, compacted and transferred in safe condition before storage (high level and nuclear hazardous radwaste). FCM accounting will ideally be in accordance with current legislation.

After FCM retrieval from the Shelter, the standard procedures of the final stage of its life cycle can be followed — decommissioning (Fig. I–17). At the stage of the Shelter decommissioning, long term risks to people and to the environment will ideally be completely eliminated. Choice of directions for Shelter transformation into an ecologically safe state will be determined by the design of Shelter decommissioning in accordance with the available technical and financial resources.

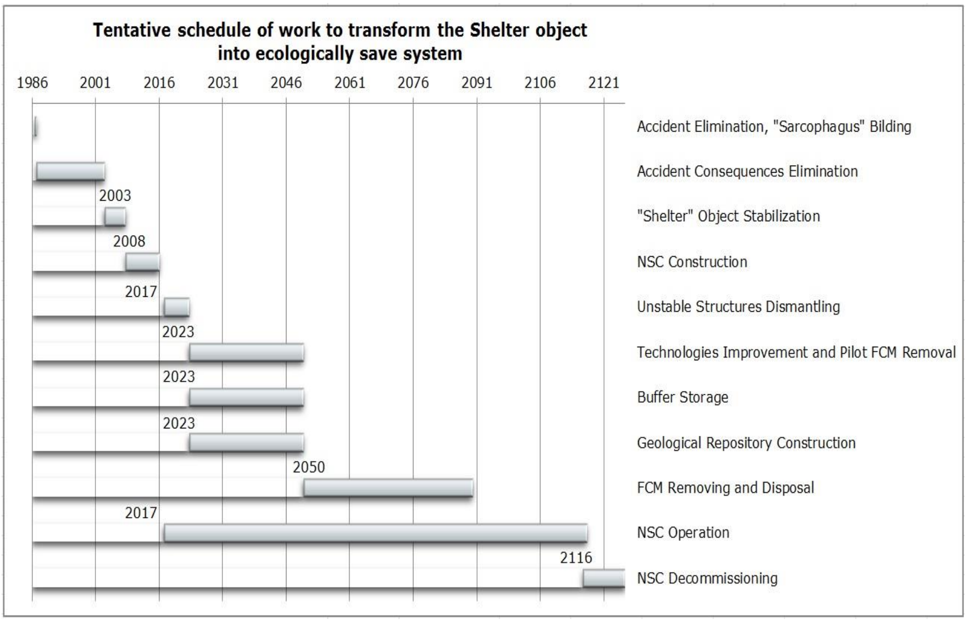


FIG. I–17. Tentative schedule of implementation of the Shelter transformation strategy (photo courtesy of Chornobyl NPP).

I–7. DEVELOPMENT OF AN INTEGRATED APPROACH TO DECOMMISSIONING AT SELLAFIELD, UNITED KINGDOM

The Sellafield Nuclear Site (hereafter Sellafield, Fig. I–18) is located on the coast of West Cumbria in the UK. Sellafield Ltd is the site licensee of Sellafield, with the UK Government's NDA owning the site. The nuclear licensed site at Sellafield covers approximately two square miles and comprises three types of nuclear reactor (a total of seven reactors) with three different generations of reprocessing facilities and all of the supporting infrastructure for ongoing nuclear operations.

These facilities range in age from those built in the 1940s right through to modern facilities built in the 2000s. Due to the complexity of operations on the site, the facilities are in a range of different stages of the facility life cycle, covering construction, operations, decommissioning, surveillance and maintenance. The purpose of this case study is to provide an insight into the development of the integration approach for the decommissioning of the Sellafield site.

FIG. I–18. Aerial view of the Sellafield site (photo courtesy of Sellafield Ltd).

I–7.1. Context

Figure I–19 shows the strategic context within which Sellafield operates.

UK Government decides the policy

NDA sets the strategy

Sellafield Ltd builds the plan for Sellafield and delivers it.

For the specific aspects related to decommissioning, Sellafield has defined a site decommissioning strategy and a decommissioning integrated strategic plan, which provides the context and rationale for the immediate period but is fully consistent with the long term objectives set out in the strategy.

FIG. I–19. Strategic context for decommissioning at Sellafield (courtesy of Sellafield Ltd).

I–6.2. Sellafield Decommissioning Strategy

For the site, the Sellafield Decommissioning Strategy is intended to provide the strategic direction for the lifetime of the site decommissioning mission, currently expected to extend to 2120. It also provides high level guidance on planning near term delivery of the decommissioning activities forming the scope of the current Remediation Operating Unit

To provide a strong focus for the strategy, the following overarching objective has been defined — The Decommissioning Strategy and its implementation plan will provide the best means to achieve sustained delivery of rapid aggregated risk reduction across the lifetime of the decommissioning mission. The strategy recognizes that delivering the greatest aggregated risk reduction at any time can be achieved by various means. It introduces the concept of risk groupings that can be managed within a framework of principles and rules to deliver sustained aggregated risk reduction. The significant projects and facilities can be categorized into the four specific risk groups that differentiate between: continued safe and secure storage of the nuclear inventory; risks posed by facilities with significant nuclear inventory present; risks posed by aged and deteriorating facilities; and projects that contribute to sustaining aggregated risk reduction.

The strategy informs the preparation of the Decommissioning Integrated Strategic Plan that will present the current programme for meeting near term decommissioning strategic objectives. The Strategy includes rules and instructions for the formulation of the Decommissioning Integrated Strategic Plan. This plan provides the justification and basis for its construction and describes any constraints that have affected decision making on apportionment of resources against the risk groupings. The Decommissioning Integrated Strategic Plan has been prepared using a ‘top down’ approach to enable programme integration and provide a composite view of risks to delivery for the overall site mission.

It is understood that while there will be further opportunities for optimization of the current output, this output is credible and deliverable. This approach has enabled learning, including that from previous Sellafield Plan builds, to be incorporated. The Decommissioning Integrated Strategic Plan addresses the following:

— Demonstrating sustained risk reduction;
— Integrating all decommissioning activities delivering rapid aggregated risk reduction;
— Credibility of individual plans and hence the integrated output;
— Recognition of the inherent uncertainty associated with individual plans;
— Deliverability influences at site and division level;
— Maintenance of a live plan.

The Decommissioning Integrated Strategic Plan has the following features:

— Logic links for leading risk reduction activities to their key preceding enabler activities (e.g. provision of waste management capability).
— Accounting for competing demand from donor facilities by prioritizing waste processing capacity based on the risk posed and the alternative routes (or options/contingencies) available for risk reduction for each facility.
— It is consistent in that common facilities have been given common assumptions. A common rate of ramp-up of scope and therefore resource deployment (based on past performance) was used to identify the optimum sequencing of the enabling activities.
— Master production schedules (or equivalent) have been built for each programme area to optimize to the most rapid credible schedule. The aggregated plan is assessed to determine potential clashes and resources are prioritized to resolve any clash. The logic links have been used to identify the impact of one programme on another where shared use of resources is required;
— Throughput assessment for the downstream waste treatment facilities has been used to ensure that the overall capacity for retrievals is credible.
— Has credibility because the key dates and assumptions have been robustly challenged to address optimism bias.
— The deliverability assessment considered the decommissioning requirements in the context of those from the rest of the site.

The Decommissioning Integrated Strategic Plan introduced the concept of the ‘Logic Aligned Master Programme’, which is a visual graphical representation of the interactions between the start of risk reduction activities and the associated enablers. These interactions are shown on a series of wiring diagrams that illustrate these interactions in a spatial sense to show the movement of materials between the different facilities. The Logic Aligned Master Programme shows the risk reduction activities as they occur in relation to time and the links between these risk reduction activities and their associated enablers.

The Division Logic Aligned Master Programme is very complex, due to the number of interactions, so it has been given colours assigned to the different programme areas and to recognize critical enablers that support multiple areas. An example of a small section of the Logic Aligned Master Programme is shown in Fig. I–20.

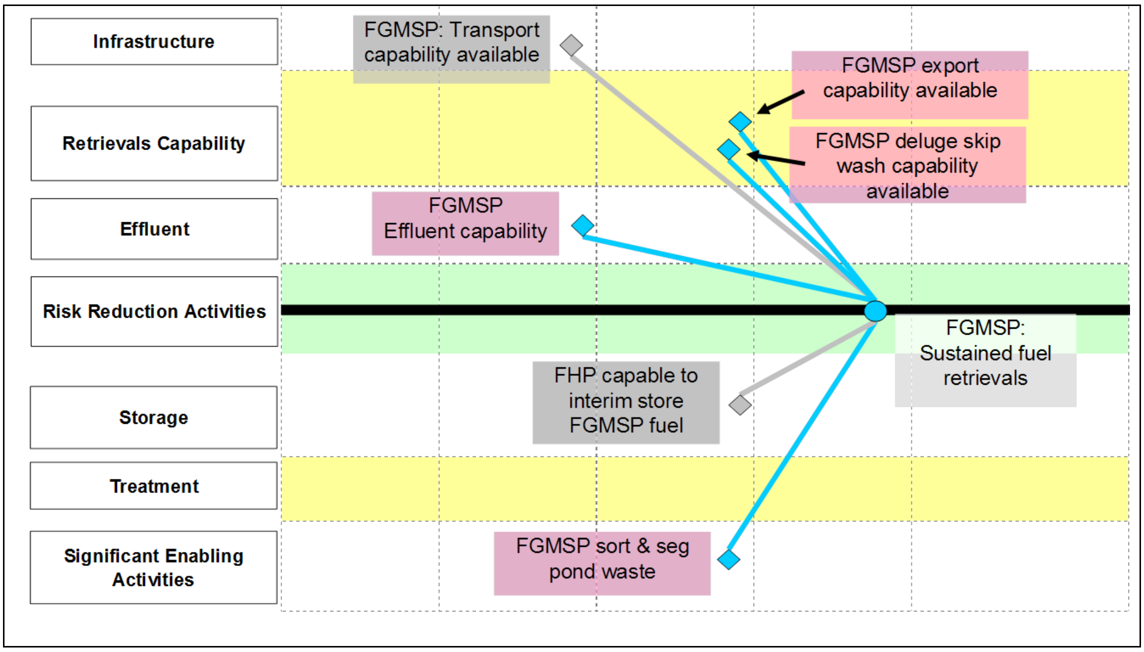


FIG. I–20. Logic Aligned Master Programme fuel export first order enablers (courtesy of Sellafield Ltd).

The Logic Aligned Master Programme shows all of the primary risk reduction activities and enablers across the Division and has been created to feed into the Sellafield Plan build process.

I–6.3. Future work

Further work is grouped into two specific topic areas: continuous improvement and development of the legacy ponds and silo programmes; development of the Sellafield Decommissioning Strategy for the phase beyond these retrievals. To improve and develop the legacy ponds and silo programmes, effective portfolio and programme management is in place to identify and respond to changes so that the plan remains integrated, credible and deliverable. A Business and Programme Integration Department within the Division has been established which strengthens this aspect of the planning process e.g. modelling local tactical plans to understand their cross programme impact. The key is to have effective reporting, live strategic planning and rapid decision-making (change control) processes on a Divisional basis. The Decommissioning Integrated Strategic Plan is a live plan and will be used to govern any changes to the strategy that are required as new information emerges.

The work on the development of the Sellafield Decommissioning Strategy is looking at how potential options for different facility end states and interim states (sensible hold points) could be best used to both drive the near-term decommissioning activity and to ensure that appropriate decision points are introduced into the future plan. An enhanced enterprise approach is also being developed to ensure the best use of existing capabilities, and to establish and implement the best value approach to introduction of additional capability to support the planned decommissioning activities across the site. Decision calendars have also been produced to provide clarity on the logic and timing of key decisions associated with decommissioning the site.

I–6.4. Conclusions

The implementation of this approach is to support coordination of activities as well as establish and provide a best value approach to delivery of the overall site decommissioning mission. The creation of a Decommissioning Integrated Strategic Plan has also provided a vehicle for explaining the overall approach being taken to external stakeholders, such as the UK regulators (Office for Nuclear Regulation and Environment Agency).

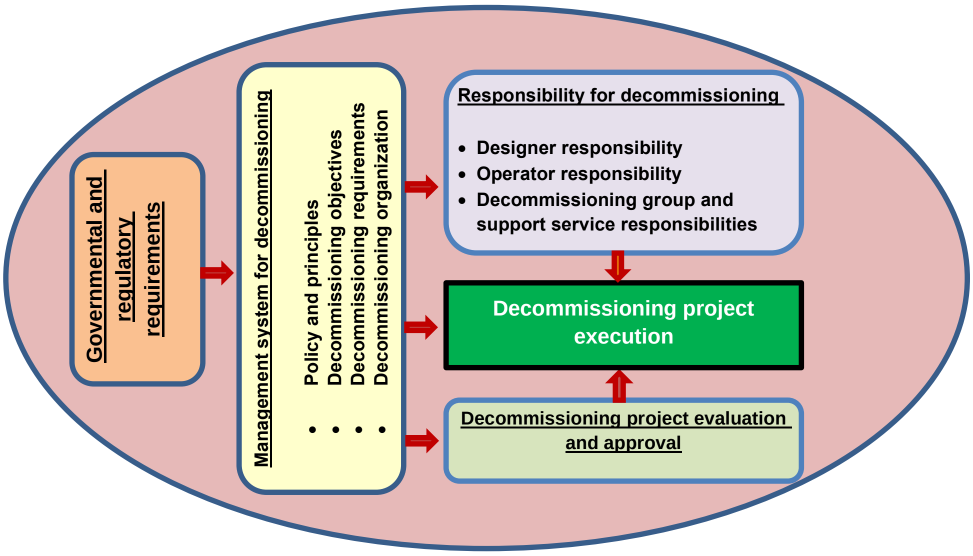
I–7. MANAGEMENT OF DECOMMISSIONING ON THE NECSA SITE, SOUTH AFRICA
A.2.

Necsa is a multifacility site that was established more than fifty years ago with construction of the SAFAR1 research reactor, the first such facility in Africa. The Pelindaba site was subsequently developed to house research, fuel cycle, isotope production, chemicals production and waste management facilities. Facilities were established with overlapping life cycles and coexist on the same site with or without interdependencies.

Although some research facilities were decommissioned earlier, the focus on decommissioning became apparent with the early shutdown of Necsa's uranium enrichment and fuel cycle facilities since the late 1980s and early 1990s. The need for decommissioning of specific facilities came at the time of establishment of an independent regulatory body and regulatory framework which reemphasized the need for a systematic approach, the justification of activities, a safety case and QA.

The management of the decommissioning at a multifacility site requires a site specific approach and strategy. This is mainly due to the existence of a multiple facilities with varied nature of activities undertaken, their interfaces and their interdependencies which are likely to complicate the management of decommissioning. The complexity of management of decommissioning at a multifacility site is intensified where some facilities are entering the decommissioning phase while others are still operational or even new facilities are being built.

The management model for decommissioning on the Necsa site included the establishment of a site wide decommissioning management system, specification of functional groups that are responsible for decommissioning management including the execution of decommissioning projects, and a project evaluation and approval process. The management model, the key components and interfaces are shown in Fig. I–21.



A.3. *FIG. I–21. Decommissioning Management Model (courtesy of Necsa).*

A.4. I–7.1. Site wide Decommissioning Management System

The decommissioning management system or a decommissioning management process for Necsa is incorporated into the site and facility specific licences or authorizations. This documented system covers the management and QA arrangements to ensure that decommissioning good practice is followed for existing and planned facilities. Specific objectives, outputs, processes and responsible functionaries are defined for decommissioning planning and projects which are verifiable at all stages of a facility's life cycle. The objective of the decommissioning policy, principles and objectives is to also reflect the requirements of all relevant stakeholders including the Governmental Department as the decommissioning liability owner and the Regulatory Authority.

The documented system includes the following general aspects/arrangements:

- Multifacility site decommissioning organization and assignment of responsibilities where different operators and support functionaries (SHEQ) coexist.
- Facility life cycle decommissioning requirements such as the decommissioning planning process covering the full life cycle of a facility.
- Specific approaches and requirements to management of interfaces that occur during decommissioning of facilities at a multifacility site.
- Arrangements to ensure proper collation and retention of facility specific information and records (facility history) over the lifecycle of facilities.
- Process for selecting and justification of facility specific decommissioning strategies, objectives and end-points as bases for the decommissioning plan.
- Content of decommissioning plans at the various facility stages.
- Decommissioning project management including project approval, execution and close out requirements.
- Reporting, closeout and delicensing arrangements.

Necsa's life cycle decommissioning and licensing requirements as well as the prescribed responsibilities are summarized in Table I–1.

TABLE I–1. SUMMARIZED DECOMMISSIONING REQUIREMENTS

Life cycle stage	Decommissioning action	Licensing requirements for decommissioning action	Responsibility
Designing of new facilities	Facility designs to incorporate features to facilitate future decommissioning considering interfaces with other facilities on site.	Submit to the Regulatory Body a part of the facility safety case as required for phased authorization	Project manager/design authority
	Initial decommissioning plan as part of the safety case of the new facility	Submit to the Regulatory Body a part of the facility safety case as required for phased authorization	Facility manager/decommissioning manager/licensing specialist
Operational facilities	Initial decommissioning plan and updated initial decommissioning plan (updated every three years)	Submit to Regulatory Body for acceptance	Facility manager/decommissioning manager

Life cycle stage	Decommissioning action	Licensing requirements for decommissioning action	Responsibility
Pre-termination of operation	Final decommissioning plan	Submit to Regulatory Body for acceptance	Facility manager/decommissioning manager/decommissioning specialists/RP and licensing specialists/waste management specialists
Termination of operation and post-termination of operation	Decommissioning plans for specific decommissioning projects (Decommissioning projects are subject to the internal project approval process)	Submit decommissioning plan including a safety assessment to the Regulatory Body as basis for decommission project authorization	Facility manager/decommissioning manager/decommissioning specialists/RP and licensing specialists/waste management specialists
	Surveillance and maintenance	Submit surveillance and maintenance plan supported by safety assessment to the Regulatory Body as bases for surveillance and maintenance authorization	Decommissioning manager/decommissioning specialists/RP and licensing specialists
	Clearance surveillance	Submit clearance surveillance plan including clearance criteria to the Regulatory Body as basis for authorization of clearance surveillance methodology and criteria	Decommissioning manager/decommissioning specialists/RP and licensing specialists
	Clearance (delicensing)	Submit clearance surveillance report to the Regulatory Body as basis for delicensing	Decommissioning manager/RP and licensing specialists

I–7.2. Responsibility for decommissioning

Necsa has established a dedicated organizational group with a site-wide responsibility for decommissioning. The responsibilities of this group include the establishment of a site wide decommissioning policy, strategy and programme, to assess decommissioning cost and to ensure that decommissioning funds are or will be available at the appropriate time. The decommissioning group is also responsible for the coordination and execution of decommissioning projects on the site with the appropriate inputs and involvement of operators of the facility to be decommissioned as well as of the operators of other facilities that may be impacted by a specific decommissioning project.

The operators of facilities are responsible for decommissioning planning with involvement of the decommissioning group, shut down and execution of at least the initial phases of decommissioning aimed at the removal of the bulk of the radioactive and other hazardous material inventories. The operators of facilities are also responsible for obtaining authorization for shut down and initial decommissioning activities. At a predetermined point the facility, within clearly defined boundaries, is transferred to the group responsible for decommissioning.

A layout of how decommissioning activities are integrated with the life cycle of a nuclear facility is presented below (see Fig. I–22): note that in the case of a multifacility site that each facility or a group of facilities have separate life cycles that are not necessarily aligned and therefore with multiple starting and transition points.

Decommissioning activity	Decommissioning considered during design/construction and initial planning.	Ongoing decommissioning planning	Final decommis-sioning planning	Decommissioning projects
Desired state	Promotion of decom. good practice attributes and establishment of decom. planning framework.	Decommissioning plan that is updated and commensurate with the operational stage of the facility and in accordance with the overall site decommissioning plan. Cost of decommissioning assessed and funds made available for decommissioning projects.	Shut down and final decommis-sioning plan	Authorized decommissioning projects or implemented surveillance and maintenance plans. Passively safe end state or released facilities.
Responsibility	Operators	Operators and decommissioning group	Operators	Decommissioning group

FIG. I–22. Integration of decommissioning related activities with life cycle of nuclear facilities.

The main advantages of a single organizational structure that is responsible for decommissioning at a multifacility site relate to improved efficiency and consistency in terms of the following:

- Decommissioning prioritization;
- Decommissioning planning including resource planning;
- Decommissioning project authorization or licensing;
- Execution of decommissioning projects;
- Waste and material management;
- Operation of facilities in support of decommissioning, e.g. decontamination and waste processing facilities;
- Surveillance and maintenance and close-out of decommissioning projects.

The establishment of a workforce that specializes in decommissioning also alleviates the ‘short term’ perception and human resource related problems associated with the transition from operation to decommissioning.

I–7.3 Site-wide decommissioning project evaluation and approval process

Decommissioning projects on the Necsa site vary in intensity and scope and are evaluated on project specific bases to determine the appropriate SHEQ and approval requirements. Decommissioning projects are, after its conceptual design phase, reviewed by a corporate specialist function that is independent from the decommissioning group to determine the project specific requirements including internal and external interfaces/requirements. The Necsa project approval process is accepted by the regulatory authority and forms part of process based licensing system. The project approval process caters for all projects on the site including decommissioning projects and provides for a corporate project evaluation function, e.g. safety and auditing.

The main advantages of a site wide project evaluation and approval process are the following:

- Consistent specification of approval and other SHEQ requirements for projects on the Necsa site that are aligned with site and regulatory requirements and conditions;
- Consistent application of the requirements of the site-wide decommissioning management system;
- Provides an opportunity for the specification of decommissioning requirements in all projects including projects to modify existing facilities and projects to establish new facilities.

I–8. APPROACH TO DECOMMISSIONING OF MULTIFACILITY SITES, RUSSIAN FEDERATION

The nuclear power and nuclear industry in the Russian Federation were operated under planned economy and State ownership so radioactive waste management and decommissioning activities used predefined plan and state funds. The challenges facing nuclear industry were mainly associated with [I–2]:

- More than 150 shutdown nuclear and radiation hazardous facilities, including NPP units and uranium production reactors;
- Engineered barrier systems for nuclear facilities and NPPs operated for more than 50–60 years and required urgent overhaul;
- The legacy sites include open water reservoirs for liquid radioactive waste (Karachay, the Techa Cascade of water reservoirs) and tailings as well as former Navy bases;
- The problems with old research reactors and laboratories which were commissioned in the 1940s–1960s;
- Accumulated SNF needing processing;
- Need in new disposal facilities for different radioactive waste classes.

I–8.1. Legislative framework

The main principles of the implementation of the decommissioning activities in the Russian Federation described in the ‘Decommissioning Concept 2008’ [I–3]. In accordance with the Concept the principles of implementing activities for the decommissioning of nuclear facilities are:

- Bring it into the state that excludes its potential nuclear hazard in the regulatory period after it has been shut down (removal of nuclear materials and spent fuel);
- Bring it into the radiation safely condition during the optimal period, considering social and economic factors;
- The maximum and cost effective release of materials and equipment;
- Implementation of technological processes and operations which will minimize volume of radioactive waste and possibility of decommissioning staff exposure;

- Final disposal of radioactive waste;
- Advanced planning and implementation of decommissioning works up to the removal of site from the state regulatory bodies.

By the mid-2000s, the situation in the sphere of nuclear legacy was as follows:

- More than 175 nuclear and radiation hazardous facilities subordinated to various federal executive bodies, including the Federal Atomic Energy Agency (four nuclear power plants, ten industrial uranium graphite reactors and more than 110 nuclear and radiation hazardous facilities for other purposes) were shut down, but not decommissioned.
- The number of near surface radwaste storage facilities ensuring reliable isolation of radwaste from the environment was not ensured; new radioactive waste disposal sites were required.
- Large volumes of radioactive waste (Techa Cascade of reservoirs, basins settling tanks and tailing dumps of organizations of the nuclear fuel cycle) not isolated from the environment.
- More than 18 500 t of SNF have been accumulated. Indicators of spent fuel storage at NPPs with RBMK and EGP-6 reactors, near-station radwaste storage facilities were close to critical levels.
- Sources of ionizing radiation were used by more than 15 900 organizations, often lacking adequate protection from terrorist danger.
- Not available due regulatory, legal and technological solutions to the problem of rehabilitation of facilities created by nuclear explosive technologies (peaceful nuclear explosions).
- Not fully implemented some of the requirements ratified by the Russian Federation in the field of nuclear and radiation safety.
- The engineering systems of a number of nuclear and radiation hazardous facilities, which were operated for 50–60 years, required urgent reconstruction and modernization.

For the comprehensive solution of the accumulated problems, in accordance with the instruction of the President of the Russian Federation of 16 March 2006, the federal target programme ‘Ensuring Nuclear and Radiation Safety for 2008 and for the Period until 2015’ had been established. For optimization of management were all nuclear facilities and NPPs converted into the joint stock companies. Also, new requirements in radwaste, SNF management and decommissioning were established and following tasks completed:

- Over 25 000 spent fuel assemblies (RBMK-1000, AMB, research reactors and nuclear-powered ships) were reprocessed or delivered to storage facilities.
- Establishment of a State Radioactive Waste Management System including creation of the National Operator and State Radioactive Waste Management Company.
- Creation of new radwaste disposal facilities.
- Different stages of decommissioning are performed for over 200 facilities, 53 of which have already been decommissioned.
- 4 259 000 m^2 of contaminated lands already remediated.
- Establishment of centres for decommissioning excellence (NPPs, production uranium-graphite reactors, SNF, etc.).

The Federal Target Programme ‘Nuclear and Radiation Safety in 2016-2020 and for the period up to 2030’ was approved by the Government in 2015. The main responsibility for its implementation is on the State Corporation ‘Rosatom’ that covers decommissioning of:

- Nuclear icebreakers called Sibir, Arctic and Russia;

- Decommissioning of buildings and constructions (14 objects) of Mayak Association;
- Decommissioning of graphite reactors of Mayak Association, Siberian Chemical Combinate and Mining-Chemical Combinate;
- Decommissioning of HEU reprocessing plant, Siberian Chemical Combinate;
- Decommissioning of plutonium processing facility, Radiochemical Plant, Mining-Chemical Combinate;
- Decommissioning of research laboratories, pilot installations and repository of nuclear materials, VNIINM;
- Decommissioning of radiochemical plant, Khlopin Institute;
- Decommissioning of burial sites and U production facility buildings, Angarsk Electro-Chemical Combinate;
- Decommissioning of building 242, Mashinostroitelny Zavod (Elemash);
- Decommissioning of SNF Dry Storage, Physico-Energy Institute (PhEI);
- Decommissioning of Units 1, 2, Beloyarsk NPP;
- Decommissioning of Heavy-Water RR, ITEPh;
- Decommissioning of buildings of Luch Plant.

I–8.2. Decomissioning

The process of decommissioning includes following key tasks [I–4]:

- The final shutdown of nuclear facility;
- Unloading and removal of SNF and NM from the facility (transfer into a nuclear safe state);
- Removal of working media, carrying out regular decontamination of equipment and premises;
- Radiation and engineering survey;
- Development of the decommissioning concept including a feasibility study and selecting the best option;
- Development of decommissioning program;
- Development of Terms of Reference for decommissioning project, safety assessment report;
- Licensing and implementation.

I–8.3. The typical decommissioning process as ‘Immediate Dismantling’

- Creation of radwaste management infrastructure;
- Decontamination and dismantling of equipment, decontamination of the surfaces, dismantling of building structures;
- Processing of accumulated and decommissioning radioactive waste, containerization, storage and disposal;
- Rehabilitation of contaminated areas;
- Removal of facility and site from the regulatory control.

I–8.4. The typical decommissioning process as ‘Safe Enclosure’

- Localization and conservation of highly contaminated equipment;
- Long-term exposure of localized equipment;
- Creation of radwaste management infrastructure (if necessary);
- Decontamination and dismantling of lightly contaminated or clean equipment, disassembly and dismantling of auxiliary buildings and structures;
- Processing of accumulated radioactive waste;

- Decontamination and dismantling of equipment, decontamination of the surfaces, dismantling of building structures;
- Processing of accumulated and decommissioning radioactive waste, containerization, storage and disposal;
- Rehabilitation of contaminated areas;
- Removal of facility and site from the regulatory control.

I–8.5. Alternative decommissioning process to establish disposal site for special radwaste

- Creation of radwaste management infrastructure (if necessary);
- Decontamination and dismantling of equipment, decontamination of the surfaces, dismantling of building structures (with the exception of the reactor shaft);
- Creation of a system of additional protective engineering barriers with the purpose of reliable localization of radionuclides in the location for the entire period of potential danger;
- Processing of accumulated and decommissioning radioactive waste, containerization, storage and disposal;
- Rehabilitation of contaminated areas;
- Withdrawal of the object from regulatory control, registration as a 'storage site/conservation/disposal site for special radwaste';
- Monitoring of groundwater, surface air, dose rate on the surface, and so on.

I–8.6. Legacy sites

The nuclear legacy in the Russian Federation came from the initial period of development of nuclear industry since the middle of the 1940s and includes [I–5]:

- Nuclear Defence Production and Tests sites;
- Radiological Accidents (Kyshtym 1957 and Chornobyl 1986);
- Spent Nuclear Fuel – about 12 000 t are kept with a total activity of about 8.2 billion Ci.;
- Research laboratories and pilot facilities;
- 650 million m^3 of liquid and solid radwaste with total activity about 2.0 billion Ci accumulated on different nuclear sites;
- Uranium mining and enrichment facilities;
- The most part of the contaminated areas (94%) are on the Mayak Combinate nearby areas.

I–8.7. Research reactors

About 55 research reactors, critical and subcritical assemblies of the total number of 103 were shut down or are under decommissioning. Spent nuclear fuel from research reactors was accumulated mainly at the sites of former and recent research and educational institutes as well as from some defence facilities. The SNF interim storage facilities are filled up to 80%.

I–8.8. Nuclear power plants

There are in total ten nuclear power plants in the Russian Federation with 35 units of following types:

- 18 units with WWER type reactors (12 WWER-1000, 1 WWER-1200 and 5 WWER-440 or smaller power modifications);
- 15 channel reactors (11 RBMK-1000 and 4 EGP-6 reactors);
- 2 fast neutron reactors with sodium cooling (BN-600 and BN-800).

According to the Russian regulatory documents (OPB-88/97), the decommissioning project will ideally be submitted for approval to the supervisory authorities five years before the end of the project lifetime of the power unit, regardless of whether its service life will be extended. Pre-decommissioning and decommissioning programmes were developed and approved for:

- Beloyarsk NPP, Units 1–3;
- Leningrad NPP, Units 1–4;
- Bilibino NPP, Units 1–4;
- Smolensk NPP, Units 1, 2
- Novovoronezh NPP, Units 1–5;
- Balakovo NPP, Units 1–3;
- Kola NPP, Units 1–4;
- Kalinin NPP, Units 1, 2;
- Kursk NPP, Units 1–4.

The funding sources to cover decommissioning costs are subsidies from the federal budget, trust funds of the federal budget and the budgets of the Russian Federation and special reserve fund created by the operator to finance nuclear facility decommissioning.

REFERENCES TO ANNEX I

[I–1] Nuclear and Decommissioning Company (JAVYS), Activities of the Company – A1 NPP Decommissioning (March 2020); https://www.javys.sk/en/activities-of-the-company/a1-npp-decommissioning

[I–2] KRYUKOV, O.V., Decommissioning and Remediation in the Russian Federation: Main Results and Future Plans; https://conferences.iaea.org/event/89/contributions/11492/contribution.pdf

[I–3] ATOMIC ENERGY, Concept of Decommissioning of Nuclear Facilities, Radiation Sources and Repository Facilities (15 December 2008); http://www.atomic-energy.ru/documents/1123

[I–4] KOMAROV, E.A., "Decommissioning of nuclear and radiological facilities. Requirements for implementors and contractors", Forum Atomex North-West, Saint Petersburg (April 2012).

[I–5] LEBEDEV, V.A., "The radiation legacy of Russia", Radiation Legacy of the 20th Century: Environmental Restoration, IAEA-TECDOC-1280, IAEA, Vienna (2002).

Annex II

LESSONS LEARNED

The following examples of lessons learned comprise an outline of the problems encountered at the nuclear facilities being decommissioned at a multifacility site. The situations are typical of the challenges that can arise when planning or implementing the decontamination and dismantling of a facility surrounded by facilities at different stages in their life cycle. Although the information is not intended to be exhaustive, the applicability of these lessons can be evaluated against a specific project. Table II–1 groups individual episodes in categories.

TABLE II–1. ISSUES ENCOUNTERED AT NUCLEAR FACILITIES

Issues	Annexes
Inadvertently impacting service lines (piping, electrical cables) belonging to, or shared with, another facility	II–1, II–4, II–11, II–16.1
Coordination between multiple entities during decommissioning work	II–2, II–7, II–12, II–15, II–16.1
Transfer of solid waste and containers between facilities	II–6
Conflicting licences between two adjacent facilities under decommissioning	II–8
Lack of retention of operator knowledge and/or inadequate record keeping	II–3, II–5, II–9
Potential impact of decommissioning work on nearby areas/facilities	II–10, II–13, II–16.3
Training and utilization of human resources during decommissioning at multi-unit sites	II–14, II–16.2
Benefits/disadvantages of centralized waste consolidation, buffer and interim storage	II–16.3, II.16.4
Shortfalls in pre-planning and strategic planning	II–16.1, II–17
Inadequate engagement with regulators	II–16.2

II–1. UNEXPECTED CONDITIONS OF ABANDONED PIPING, USA

Problem encountered. Prior to the demolition of a facility adjacent to a large process building, the utilities connecting the two facilities were to be isolated and air gapped. Multiple utilities travelled between the two facilities including one 4 in (10 cm) line identified by labels as ‘air’ at one location on the pipe and ‘water’ in another location on the pipe. During an extensive effort to identify an isolation point, it was discovered the line had previously been air gapped and plugged with grout inside the process building. There was no evidence of the original piping it was once connected to. Once the line was verified isolated, a cut was made between the two buildings to create an air gap. After making the cut, the workers noticed the pipe contained small beads of mercury. It was later discovered that the inside of the pipe also had radiological contamination. The outside of the pipe at the cut location had been checked prior to the cutting and no radiological contamination was found. The discovery of mercury and radiological contamination inside the pipe was an unexpected condition [II–1].

Analysis. Due to the necessity to identify an isolation point, a great amount of effort was spent looking at existing drawings and performing field walkdowns. The discovery of the isolation point only occurred after performing a hand-over-hand walkdown in a congested overhead pipe gallery. The configuration of the 4 in line led the project team to believe this was an abandoned airline. Additionally, since only grout had been used to fill the open end of the line rather than mechanical device, there was no reason to believe it contained a hazardous material. It is still not known what the function of the pipe was or why it contained droplets of mercury and radiological contamination.

Looking back at the conditions leading up to the event, the following will ideally have been taken into account:

(1) The pipe had two different labels indicating the pipe's function. Labelling may have occurred a number of years after installation as part of a new requirement or corrective action. The labelling may not have been performed correctly.
(2) Since the pipe had already been air gapped and no piping remained at the disconnect point, the system function could not be verified back to an active distribution header.
(3) Due to these two existing facility conditions, the facility's operating history will ideally have been considered in determining the controls necessary to execute the work.

In addition to an impact on the project schedule, the failure to plan for the unexpected condition resulted in additional costs being expended to analyse the incident, perform surveys of the pipe and surrounding areas, order bioassays of impacted personnel, and a rework of the work package.

Lesson learned. When working on abandoned piping in process buildings, anticipate encountering unexpected conditions inside the piping until otherwise verified. The impacts of inaccurately checking conditions may be more significant in piping connecting two separate facilities.

II–2. COORDINATION WITH MULTIPLE ENTITIES PERFORMING WORK ACTIVITIES ON THE DOE–OWNED PADUCAH SITE SO THAT ALL DIRECT AND INDIRECT HAZARDS ARE EVALUATED AND CONTROLLED, USA

Problem encountered: On 20 August 2007, two electricians wearing powered air purifying respirators made a permit required confined space entry in a manhole, as indicated on the 'Personnel/Atmospheric Testing Log' to complete the removal of asbestos insulation from electrical cable. An electric spot cooler was used to reduce the interior manhole temperature and supply a constant flow of outside air. Unrelated work by another organization was being performed about 75–100 ft due south of the manhole (25–33 m). The unrelated work involved two diesel powered generators for welding and an air compressor. The confined space work team was not aware that the unrelated work was going to be performed at the same time and did not immediately recognize a potential for migration of exhaust gases into the confined space [II–2].

Analysis. There was no prior coordination between the two work crews to ensure that there were no direct or indirect interferences based on the work that each was performing and it was not immediately recognized, by either work crew, that there was an unexpected change in condition that could potentially create a hazardous situation.

Lessons learned. During the planning, preparation, mobilization, execution, and restoration activities it is important to understand the work that may be performed by other organizations and contractors in the vicinity so that all potential hazards can be properly evaluated and control ed to ensure that work objectives can be met successfully. In particular, the following actions will ideally be considered:

(1) Work activities need to be coordinated with the other groups working in the area around the confined space to ensure that unrelated activities did not impact the workers in the confined space.
(2) In the event work activities have not been coordinated prior to starting work each day, the field supervisor will ideally stop the work for which he is responsible and contact the supervisor of the unrelated work.
(3) Consider potential sources of vapours and gases (i.e. exhausts, tanks, processes, etc.) that could enter into the confined space and expose entrants to unsafe levels of hazardous materials or that could displace oxygen levels creating a hazardous condition.
(4) Perform a walkaround (recommend 150 feet — 50 m — radius) of the surrounding work area before each entry to ensure no additional sources of hazards are being generated and be aware of changing conditions while the work is in progress.
(5) Entrants and attendants will ideally be reminded to stop work and assess the impact and controls anytime there is a change in condition or work area that could potentially create a new unrecognized hazard.

II–3. FERMI 1 NPP RESUMING DECOMMISSIONING AFTER A LONG PERIOD OF SAFE ENCLOSURE, USA

The Enrico Fermi Atomic Power Plant, Unit 1 (Fermi 1) is located in Michigan, USA. The site boundary is completely contained within the Fermi 2 site boundary, adjacent to Lake Erie. Fermi 1 was a fast breeder reactor power plant cooled by sodium and operated at essentially atmospheric pressure. The reactor plant was designed for a maximum capacity of 430 MW(th); however, the maximum reactor power with the first core loading (Core A) was 200 MW (th). The primary system was filled with sodium in December of 1960 and criticality was achieved in August 1963. In 1972, the core was approaching the burnup limit. In November 1972, the Power Reactor Development Company made the decision to decommission Fermi 1. The fuel and blanket subassemblies were shipped off-site in 1973. The non-radioactive secondary sodium system was drained and the sodium sent to Fike Chemical Company. The radioactive primary sodium was stored in storage tanks and in 55 gal (200 L) drums until the sodium was shipped off-site in 1984. The first phase of decommissioning of the Fermi 1 plant was originally completed in December 1975, then the reactor remained in a safe storage condition for over 20 years. There is no spent fuel on-site. Bulk sodium has been removed from the site, and the reactor vessel has been grouted and is being removed. The facility transitioned from active decommissioning in 2011 and returned to safe storage in early 2012 [II–3–II–5].

Problems encountered. The following selection of personnel issues refers to a decommissioning phase in the late 1990s (25 years after final shutdown) when management started to determine the condition of Fermi 1 systems and structures and launch some short term actions in preparation to another safe storage phase.

Over the long time when Fermi 1 had been idle, some staff and labour personnel left or were temporarily reassigned. This limited the capability to complete work, in addition to the knowledge loss and additional training costs incurred due to retirements and replacements. Also, since Fermi 1 was not making the company any money, the company focus was to use available personnel to support plant outages at Fermi 2 whenever possible. This resulted in further loss of personnel for Fermi 1 decommissioning project.

While being located on the same site of the operating Fermi 2 NPP had some benefits, it also had some drawbacks. The benefits included access to equipment (e.g. crane, tool crib etc.), personnel (e.g. radiation protection, environmental, etc.) and pre-approved programmes (e.g. safety tag outs, radiation protection procedures etc.). Some of the drawbacks were locked into unwanted Fermi 2 programmes (e.g. purchasing), heightened nuclear security (i.e. added difficulty to get material and personnel on-site), and to have to always keep in mind how Fermi 1 related actions would impact Fermi 2. Since there was no fuel onsite at Fermi 1, the heightened nuclear security would not be required if Fermi 1 were not on the same site as an operating NPP.

When decommissioning work was resumed after 25 years, there were few personnel available familiar with the plant and how systems were left. For instance, they found sodium in inert gas lines where it was not expected due to lack of knowledge of how the plant was laid up.

Finally there was the underlying desire for people to do not want to work themselves out of a job. There were several personnel that viewed Fermi 1 as a place to retire from, and for a few of them, it was actually so.

Lessons learned. Long period of safe enclosure in general results in loss of knowledge, demotivation of personnel, and a general perception of low priority. Operation of another nuclear facility at the same site might bring some benefits to resolve this issue.

II–4. GOOD WORK PRACTICES WHEN EXCAVATING IN AREAS CONGESTED WITH BURIED UTILITIES, USA

Problem encountered. An undocumented and undetected buried electrical cable was encountered during hand excavation for a new water line. During preparation of the excavation permit for the work a search for as-built drawings was performed. Utility scans completed before excavation indicated that buried utilities were present in the areas. However, the encountered electrical power cable was not detected during the utility scans. The excavation permit and work package specified hand digging of the trenches because buried utilities were known to exist in the work area. Instructions in the excavation permit specified “When anything unusual or unexpected is identified in an excavation, STOP and carefully hand dig until the discovery can be properly evaluated”.

During hand digging of the water line trench, an undocumented (not on an as-built drawing or identified by utility scans) buried electrical cable was encountered. The workers stopped work and contacted the responsible manager. the trench was inspected by the responsible manager, work supervisor, and electrical subject matter expert. An electrician was also brought in to investigate the cable. The electrician checked the undocumented cable with a proximity voltage tester and determined that the cable was not energized. Next, the workers investigated the routing of the cable and determined that it ran into an electrical conduit which was connected to a fuse box. The fuse inside of the box was turned in a manner so that the connection was de-energized. Work was then paused and management was notified.

A work package was issued to perform a facility outage. The main power feed to the trailer complex was isolated, utilizing the hazardous energy control procedures, and the undocumented cable was removed. The other electrical utilities (in use and abandoned) located at the trailer complex were also documented during the outage [II–6].

Analysis. Temporary office trailers and associated utilities were installed in the work area to support a previously (about ten years prior) completed construction project. After the construction project was completed, the temporary trailers were removed. However, some of the associated electrical cables (without marking/locator tape) were not removed. As-built drawings did not show all of the remaining, abandoned electrical cables. In addition, utility scans did not identify the undocumented buried cable.

As explained in several existing DOE lessons learned (SWPF-LL-134, 2003-NV-NTSBN-001, L-2001-OR-BJCPORTS-1101, 2001-RL-HNF-0022) no single utility location instrument can detect all types of buried utilities or all buried utilities in areas congested with utilities or other interferences (near buildings, fences, other utilities, etc.).

In addition, proximity voltage testers are not to be used to verify an electrically safe work control boundary. Even if the tester determines that a cable is not energized, the tester cannot ensure that the cable will remain de-energized during the work.

Lessons learned. Excavation in areas congested with buried utilities or in areas where previous activities likely required buried utilities presents a risk to discover undocumented or undetected utilities. Extra caution will ideally always be taken when excavating these areas. Specific actions to consider include:

- Perform walkdowns of work areas to identify physical conditions that may indicate the presence of anomalies (i.e., disconnect box with no associated power line, exposed cables not previously identified, indications of disturbed soil, etc.);
- Research as-built drawings and previous site activities and uses to identify buried utilities and potential locations for abandoned utilities;
- Use hand digging in areas congested with known utilities or in areas where the site history indicates that abandoned or undocumented buried utilities are likely to be encountered. If possible, isolate the main electrical feed into the trailer/facility complex prior to performing the work;
- Use utility scans to determine location of buried utilities and remember that not one type of utility locator can detect all types of utilities, especially in areas with other interferences (buildings, fences, other utilities, etc.). Do not rely on utility scans to be the single line of defence;
- Do not use proximity voltage testers to determine or verify an electrically safe work condition. Even if the tester determines that a cable is not energized, the tester cannot ensure that the cable will remain de-energized during the work. Utilize hazardous energy control procedures (lock and tag) when performing investigations;
- Require as-built drawings to be issued for utility installations, removals, and modifications;
- Include the removal of utilities during demobilization activities. If utilities are not removed ensure as-built drawings are issued showing location of abandoned utilities;
- Notify management when electrical anomalies or unexpected conditions not covered in a work package are encountered;
- When taking over responsibility for facilities and trailer complexes, ensure pre-existing surveys include locating as-built drawings for the utilities.

II–5. LEGACY CONTAMINATION AT 420-2D DECOMMISSIONED PAD: EMPHASIS ON TRACEABILITY OF ACTIONS FOR IMPACT ON FUTURE ACTIVITIES, USA

Problem encountered. In preparation for the project for the D-Area Concrete/Soil Removal Action at the Savannah River Site, Radiological Protection personnel were probing the building pads that were to be made rubble and placed in the heater pit. During the probe of the 420-2D (Zone E) slab, 6000–8000 dis./min beta-gamma (100–130 Bq) was detected in an ~5 ft × 5 ft area on the southwest corner of the pad with a centre small area ~2 in × 4 in (~50 cm^2) probing 14 000 dis/min (230 Bq) beta-gamma.

The pad is located within a posted Controlled Area, but there was no posting or labelling of the pad indicating the presence of the contamination. Health physics (HP) technology personnel were contacted and performed an isotopic analysis, finding ^{137}Cs as the predominant isotope.

The 420-2D building was decommissioned during fiscal year 2005 and left posted as a fixed contamination area due to several spots of fixed contamination on the slab. Due to its close proximity to the 420-D facility, the slab was later covered during fiscal year 2006 with crusher run to support the crane operations necessary to support the decommissioning activities for that facility. At this time, the area was still posted as a Controlled Area/Underground Radiological Material Area (URMA).

When 420-D decommissioning was completed, the crusher run was left in place, and the 420-2D slab was still covered. The area still remained posted as a Controlled Area/URMA.

When the legacy contamination was found during the survey, it was a rediscovery of the fixed contamination that existed on the pad following decommissioning and prior to its being covered with the crusher run. Reviews of other work associated with the area from the 2006 to 2010 time frame did not reveal the exact timing or any documents related to the removal of the URMA postings [II–7].

Lessons learned. Personnel performing decommissioning related activities need to be cognizant of the traceability of their actions for future area closure related activities. Personnel performing area closure activities need to also be cognizant that existing visible conditions and postings (or lack thereof) do not necessarily provide all of the information necessary to address potential hazards during activities that disturb the soil or ground covering. Reviews of previous work will ideally be conducted to ensure adequate understanding for potential hazards that may be found as the soil or other ground covering is disturbed and removed.

II–6. LIQUIDS, PRESSURIZED AEROSOL CANS AND OTHER PROHIBITED ITEMS IN LEGACY WASTE CONTAINERS, USA

Problem encountered. As part of a risk reduction effort by Bechtel Jacobs Company (BJC), specific transuranic (TRU) waste containers were to be relocated from one facility to multiple facilities. While reviewing container waste data, a real time radiography (RTR) printout was discovered that indicates specific 55 gal (200 L) drums may contain liquid volumes greater than 0.5%, pressurized aerosol cans, and other prohibited items. The current safety basis analysis did not adequately address the impacts of these items inside the drums [II–8].

Analysis. The design analysis calculation (DAC) for waste storage facilities was written in 1996 by the prior prime contractor in support of the Safety Analysis Report (SAR) for the facilities. At the time the DAC was written, the developers of the analysis considered that hazardous liquids and flammables inside the legacy TRU waste containers would be of concern in an extreme fire event. However, consideration was not given during the analysis to the reactions of free liquids, aerosol cans and gas cylinders inside the containers and the postulated exposures that could result from their reactions during a severe fire event. The presence of these prohibited items had been discovered during RTR testing during the late 1980 to early 1990 timeframe. Printout reports from the RTR testing had been filed with some of the original container data packages, but were not included during the development of the DAC. This fact led to the inadequate analysis when the DAC was developed in 1996. The facilities had continued to operate under the 1996 DAC analysis and corresponding safety basis until the RTR test reports were discovered during a transportation DSA review that was being performed in May 2003 to support relocating the drums from building 7842.

Lessons learned. As an industry, such as the handling and storage of hazardous wastes, evolves, so does the knowledge and standards by which that industry is regulated and controlled. Previous concepts and assumptions regarding safety factors and possible impacts on worker safety, the public or the environment need to be re-evaluated to determine whether those concepts and assumptions remain valid, especially in case of transportation and re-location to other facilities.

II–7. SHIELD BLOCK SPACER FALLS ONTO AN OPERATOR’S FOOT AT ORNL MELTON VALLEY’S 7841 SCRAP YARD, USA

Problem encountered. On 13 October 2005, at the ORNL Melton Valley Completion Project's (MVCP) 7841 Scrap Yard Facility, a subcontractor was re-wrapping spacer plate keys that serve to provide specific spacing between shield blocks, used as shielding for underground cells at the Molten Salt Reactor Experiment (MSRE). The activity involved moving the shield plates from the scrap yard and placing them in a Sealand container at MSRE. The blocks were being removed from the scrap yard to aid the MVCP D&D Project in cleanup of the 7841 Scrap Yard Facility.

The work was being done for the ORNL Melton Valley MSRE Facility. The work was physically being accomplished for MSRE by a subcontractor. The subcontractor’s normal work alignment is through BJC’s Waste Management Organization. The work was taking place in the ORNL Melton Valley 7841 Scrap Yard Facility.

The work package contained the required information for performance of the work activity, i.e., job walk down, pre-job briefing, job instructions, Blocking/Bracing Plan, AHA, etc. During pre-job planning discussions, the possibility of the plates sliding was addressed. It was concluded the weight of the plates (~250 lb each (120 kg) resting on the 6 in × 6 in (15 cm × 15 cm) wooden blocks would prevent the plates from sliding.

On 5 October 2005, all notifications were made by the subcontractor for the scheduled work in the MVCP’s 7841 Scrap Yard. The work package had been previously reviewed by the MVCP's 7841 Scrap Yard facility manager and authorized. A pre-job briefing was conducted on the work package. Daily pre-job briefings included the use of the Safety Task Analysis Risk Reduction Talk Card as a tool for review of potential hazards. Due to ergonomic factors it was determined to leave the shield plates in their current stacked configuration for the re-wrapping. Each stack was to be raised to allow the placement of heavy plastic to be used for the re-wrap. Once the top layer was wrapped, it was to be moved to allow access to the next set of shielding plates. The process was to continue until all three sets had been re-wrapped. On 5 October 2005 the subcontractor contacted the 7841 Scrap Yard’s facility manager and the HP Lead for the scrap yard as required prior to the start of work. Due to rain and other factors no field work was performed on this task between 5 October 2005 and 13 October 2005. On 12 October 2005, the subcontractor’s Transportation Specialist called the 7841 Scrap Yard's facility manager requesting a HP shipping survey. The survey was needed for the shield blocks that were previously wrapped and staged outside of the 7841 Scrap Yard Facility fence. No mention was made relative to the subcontractor restarting work on the remaining shield blocks or lifting beams. On 13 October 2005, the subcontractor contacted the HP Lead for the scrap yard to let him know they would be working that day. The HP Lead allowed access to the 7841 facility. Based on communication with the HP Lead during the 5 October 2005 work performance the subcontractor assumed that the 7841 facility manager had been notified by the HP Lead. The subcontractor did not contact the facility manager responsible for the 7841 Scrap Yard. As a result, the subcontractor was in the 7841 Scrap Yard Facility performing work without facility manager knowledge or authorization. The MSRE was carrying the work scope on their plan of the week schedule but was not informed that the subcontractor was to recommence work on 13 October 2005. The MSRE facility manager was not notified that this work scope was to restart on 13 October 2005.

The top stack was raised using a fork truck and a sheet of heavy plastic was spread under the shield plates and on top of the wood cribbing. The shield plates were placed back on top of the cribbing. Three subcontractor employees, one on each end and one on the side of the plate pulled on the plastic in order to tighten prior to taping. The shield plate slid on the cribbing causing the plate and cribbing to tilt and the plate to fall approximately one and a half foot to the ground. The employee injured was unable to move his left foot clear of the falling plate. The employee was wearing steel toed boots at the time of the injury. The employee was diagnosed with 3 metatarsal bone fractures and was referred to an orthopaedic specialist.

At the time of the accident the subcontractor notified their BJC subcontract coordinator who notified the appropriate personnel in the BJC Waste Management Organization. The subcontractor removed their employee from the site to obtain medical treatment. The facility manager for the 7841 Scrap Yard and the facility manager for MSRE were notified of the incident. The Waste Management Organization notified their appropriate Waste Management DOE Facility Representative and the MSRE facility manager notified the MSRE DOE Facility Representative. The MVCP 7841 Scrap Yard facility manager did not directly notify their DOE Facility Representative.

The subcontractor operator was taken immediately to East Tennessee Technology Park Medical for treatment where he was X rayed and a preliminary report indicated the foot was broken in three places. He was not taken off-site for immediate treatment. An initial critique of the incident and work scope was conducted to determine if any additional safety and health issues needed to be implemented in the existing activity hazard analysis and work package.
A follow-up critique was held between BJC and the subcontractor and several instances of failed communication were noted. Communication requirements were reemphasized before work was allowed to continue within the 7841 Scrap Yard Facility footprint [II–9].

Lessons learned. The organization charged to perform a scope of work will ideally ensure that the facility manager responsible for the facility where the work is to take place has authorized facility access and the work scope prior to initiating physical work activities. If multiple facilities are involved, as in this case, the facility managers for the facilities involved are responsible to communicate with each other and ensure there is a clear understanding of the work scope, its impact for both facilities, the work performance schedule, the work performing organization, its work supervisors and personnel responsible for the satisfactory completion of the work scope and each facility manager’s individual responsibilities relative to the work (start to finish). The work scope and schedule will ideally be discussed in both facilities’ plan of the day meetings prior to the initial start of the work scope and prior to any restart after a break in work performance. Work progress will ideally be checked periodically until completion. There will ideally be a clear understanding that the facility manager responsible for the facility where the work is to take place is the individual that authorizes access and approves work within that facility.

II–8. DECOMMISSIONING OF RESEARCH REACTORS RITMO AND RANA, ITALY

Problem encountered. The two zero power reactors Ritmo and Rana were situated at the Casaccia Research Centre, near Rome. Ritmo and Rana were adjacent pool-type reactors separated by a gate. Either facility/site (the pool) was separately licenced (see Figure II–1).

The two reactors were dismantled in 1984-1985 (Ritmo first, and Rana a few months later). Contamination/activation detected during dismantling was almost nil in either reactor. At that time, Italian legislation gave no indications on the procedure to follow for decommissioning and licence termination of nuclear installations. In lack of specific guidance, the Ritmo pool was surveyed at the end of dismantling and its licence was terminated — before the Rana works were completed. The Rana pool had still some remaining water, which later leaked out to the adjacent- already de-licenced pool.

Analysis. It was readily ascertained that the leaked water was not contaminated and no radiological contamination resulted from this incident.

Lesson learned. The licence of a decommissioned facility will ideally only be terminated if assurance is provided that neighbouring facilities under decommissioning will not re-contaminate the decommissioned part of the site.

FIG. II–1. The two adjacent pool type reactors, Rana and Ritmo, Italy.

II–9. REUSE AND REDEVELOPMENT COMPLICATED BY DRAINS LEGACY, UNITED KINGDOM

Problem encountered. A complex nuclear research site with hundreds of buildings utilized a network of drainage systems, developed over decades, to connect the buildings to a central liquid effluent treatment plant. The drains included:

- Local soakaways;
- Networked industrial effluent systems which were nominally non-radioactive;
- Old generation active drains with no secondary containment;
- Modern active drains with secondary containment;
- Rainwater drains.

The problems included:

— Generations of successive drains and delay tanks had been installed with no decommissioning of old systems;
— Drains were sometime collapsed or leaking;
— Inactive drains had been used for active effluents by mistake;
— Not all drains were recorded on site drawings;
— Some drains had been decommissioned but there were no records kept;
— Some drains had been grouted in-situ with inadequate survey records to justify the drain being left;
— Rainwater was entering into drains creating additional effluent.

Analysis: A programme of drains decommissioning was established to enable site redevelopment. The remaining buildings requiring drainage were isolated with dedicated systems. The remaining network of drains was decommissioned in a manner to regain confidence in the eventual land quality. It included:

— Drains detection and mapping;
— Use of a geographical information system to record and map progress;
— Flushing of drains;
— Contamination monitoring using a pipe crawling robotic probe;
— Removal of collapsed sections;
— Grouting in-situ of all cleaned drains to avoid unnecessary excavations.

Lessons learned. Progressive decommissioning of redundant systems during the phase of site operations is beneficial to reuse and redevelopment of the site. Record keeping is very important in order to justify the final land quality status. Drains may be suitable for reuse (the rainwater drainage system was reused on this site) or may have to be decommissioned. Decommissioning may not require excavation and removal if grouting in-situ can be justified.

II–10. DECOMMISSIONING AND DISMANTLING OF THE MOATA REACTOR, AUSTRALIA

Problem encountered. The MOATA ARGONAUT type reactor was constructed at ANSTO (Australia) in 1961. It was built as a 10 kW reactor, but modified in 1972 to 100 kW. It had graphite moderator / reflector (12 t) and was cooled by light water. The shielding consisted of high density and low-density concrete. Preliminary dismantling started in July 2009, while the biological shield was dismantled in 2010. A specific problem was that MOATA was housed in the same building as an adjacent Tandem Accelerator. The challenge was the accelerator sensitivity to ^{14}C (1×10^{-14}). This posed a serious risk to the future of carbon dating programme and research at the ANSTO research centre [II–10, II–11].

Analysis. The following measures were taken to confine any dust produced by MOATA dismantling (Fig. II–2):

— Localized tent and extract;
— Fully enclosed and tented work:
- Double skinned,
- Air inflow through tent skin.

— Extract filtration:
- Primary dust,
- Secondary HEPA extract filtration.

Lessons learned. The presence of adjacent facilities may imply extra precautions during dismantling.

FIG. II–2. Removal of concrete block at Moata reactor, Australia (courtesy of ANSTO).

II–11. ABANDONED SYSTEMS ENERGY STATUS, IDAHO NUCLEAR TECHNOLOGY AND ENGINEERING CENTER, USA

Problem encountered. On 2 March 2009, Utility Operations personnel noted abnormal cycling of the Idaho Nuclear Technology and Engineering Center (INTEC) fire water service pumps and notified the INTEC plant shift manager. Upon extensive investigation they located a leaking water line in building CPP-621. This particular line was a two foot section of two inch line that protruded from the building slab and was capped on the end. This line had apparently frozen and ruptured the capped end inside the building. They isolated the line by closing a valve below the rupture point.

Upon further investigation, D&D personnel determined this water line was part of a legacy raw water system that resided in some older buildings at this site and was supplied from the fire water system. This line also likely supplied the buildings original potable water system. In recent years a concerted effort had been undertaken to separate the potable water systems from the fire water systems, yet some buildings still have the original pipe stubs connected to the fire water system as is the case in this event.

The D&D organization participated in a facility turnover walkthrough with the previous owner and during the walkthrough the line was identified by the previous owner as inactive. The turnover checklist generated by the previous owner in conjunction with D&D did not list this line or the raw water service as an active system. During the work package planning stage, the search for active utility systems did not reveal this line as an active system on any active drawings.

The planning walkdown for this work package did not identify this line as being connected to an active system. D&D personnel assumed that this line was inactive based on the lack of supporting evidence to the contrary [II–12].

Analysis. Demolition of facilities, and in particular older facilities, requires in-depth planning and engineering to ensure all systems are identified, isolated, and air gapped as necessary. It is critical that the up-front planning includes searches of databases for not only active but also inactive drawings. When active systems are unintentionally encountered during demolition or excavation it seems they can always be located on a print somewhere, after the fact. Physical appearance can reinforce misconceptions about the configuration of a particular system as was the case in this event. The pipe stubbed out of the floor with a cap in place and an open valve below the cap reinforced the assumption that this line was inactive as indicated by the absence of it on the building utility prints. This line did appear on an inactive Aluminum Nitrate Filtration System print that was found after the event and was designated as a raw water line. The raw water was used to back flush the filters on the old filtration system. This building and its associated utility systems was built in the mid-1950s. The Aluminum Nitrate Filtration System was removed over 20 years ago so the availability of personnel with historical knowledge is limited. The key to ensuring that all systems have been identified is the reconciliation of all discrepancies between the actual facility configuration and the building drawings, both active and inactive. Also, inactive or abandoned systems may still contain hazardous energy, materials that are not compatible with the environment, or may still be physically connected to active systems.

Lessons learned. Abandoned/not in-service systems will ideally not be considered as isolated until a positive zero energy check is completed.

II–12. SAFETY BASIS CHANGES REQUIRE ADEQUATE ANALYSIS AND REVIEW, IDAHO NATIONAL LABORATORY, USA

Problem encountered: On 20 January 2014, a positive unreviewed safety question determination was declared revealing an inadequacy in the documented safety analysis for remote–handled TRU (RH TRU) waste operations in the New Waste Calcining Facility (NWCF) at the Idaho National Laboratory.

The issue was self-identified from questions that arose related to the assumptions in the source term (ST) calculation for the NWCF high-efficiency particulate air (HEPA) filter degradation accident scenario. This scenario addresses the consequences of a release from the HEPA filters in the ventilation system for the entire facility. The ST calculation currently in the NWCF SAR is for the tank farm facility (TFF) liquid waste processing operations that are no longer performed in the facility. The ST calculation does not include RH TRU waste repackaging operations currently performed at NWCF. The material at risk associated with the TFF waste consists of high concentrations of gamma emitters and low concentrations of alpha emitters. Whereas the material at risk associated with the RH TRU waste consists of high concentrations of alpha emitters and low concentrations of gamma emitters. Adding the RH TRU waste ST to the accumulated TFF ST on the HEPA filters will result in a higher consequence from the HEPA filter degradation accident scenario [II–13].

Analysis. As is typical with many older facilities, the NWCF safety basis has evolved over time. The TFF consists of underground tanks that collected liquid wastes from the reprocessing of nuclear fuel. This waste was transferred to the NWCF where it was treated using a fluidized bed process that converted the liquid waste to highly radioactive granular solids. The characteristics of TFF waste were considered in the ST calculations for consequence analyses in the NWCF SAR. Calcining operations in the NWCF were stopped in 2000, however the ST for the TFF waste was still considered the bounding material at risk for evaporation activities that continued to be performed in the facility.

It was determined that RH TRU waste repackaging would be added to the scope of work performed at the NWCF. At this time, it was also determined that there would be two nuclear facility managers (NFMs) at the NWCF. One NFM would be responsible for the RH TRU activities and the other NFM would be responsible for all other activities at the facility. The NWCF SAR was revised in 2006-2007 to include RH TRU repackaging operations that are now performed in the NWCF. However, this revision did not update HEPA filter degradation accident scenario to include the ST for RH TRU waste repackaging.

Due to the time that has lapsed since the SAR revision in 2007 and the relocation and retirement of individuals directly involved with the revision, the investigation into the cause of this oversight could not identify why the NWCF HEPA filter degradation accident scenario was not updated to include the ST for RH TRU waste repackaging. It is possible that those involved in the SAR revision at the time erroneously assumed that the TFF ST would be bounding for RH TRU repackaging. It is also possible that re-analysis of the ST was inadvertently missed due to the large number of changes to the SAR, the shared responsibility between two NFMs, and multiple safety analysts involved in making the changes. In addition to adding the RH TRU waste repackaging scope, the annual SAR update and two other scope changes were also included in the SAR revision. The safety analysts involved with the change were also in transition at the time. The safety analysts for RH TRU may have erroneously assumed that the HEPA filter degradation scenario was only for other operations performed in the NWCF. It is noted that DOE-STD-5506-2007, “Preparation of Safety Basis Documents for Transuranic (TRU) Waste Facilities” issued at about the same time period that the SAR was being revised, specifies the accidents that will ideally be analysed for a TRU waste facility in Table 3.3-1. DOE-STD-5506, Table 3.3-1 does not specify a HEPA filter failure event as one of the events recommended for analysis for a TRU waste facility.

Lessons learned. Nuclear facility safety basis documents will ideally be carefully reviewed when implementing new work scope, especially in shared facilities where there are multiple NFMs and nuclear safety analysts, when there is a significant change or addition to the isotopic profile, and/or when implementing more than one change in scope.

II–13. ASSESSING CHANGING CONDITIONS DUE TO HAZWOPER REMEDIATION ACTIVITIES

Problem encountered. On 4 November 2010, during remediation activities in the East Yard of the Old Salvage Yard (OSY), funded by the American Recovery and Reinvestment Act, a small piece of metal (approximately 1 in × 2 in × ½ in (2.5 cm × 5.0 cm × 0.75 cm) was discharged during shearing operations. The metal travelled approximately 200 ft (70 m) across the yard and made contact with the back of a metal chair which was occupied by a subcontractor. Upon striking the back of the chair, the metal dropped to the ground. There were no injuries to the subcontractor and no visible damage to the chair [II–14].

Analysis. The OSY is a HAZWOPER site and multiple activities have occurred to remediate the Site. As the OSY remediation activities have progressed, several very large and/or very dense/hard objects have been discovered that require shearing to meet the waste acceptance criteria of the intended disposal facility. These objects were either too large or dense/hard for the smaller shears that have been operating in the OSY. Accordingly, these objects were segregated for campaigning when a large shear could be brought onsite. The large shear was being used to size reduce these materials when the incident occurred. A 150 ft (50 m) radius around the operation of the large shear was being used as a standoff distance.

Small shears and grapples have been used for metal size reduction in the OSY until use of the big shear was required. For over 90% of these small operations, “natural” barriers and shields were in place in that there were initially five huge piles and approximately 1200 stacked boxes that acted as shields, and as work progressed, additional smaller piles emerged and also acted as shields and barriers for the surrounding size reduction operations. As piles started shrinking due to the disposition of the metals off-site, more open space resulted, and when large shear operations began, the number and size of barriers was minimal. A centralized location for big shear operations that had a natural embankment on one side was chosen, and when available, some large tanks and other large items were strategically positioned around the big shear operations to act as a shield or barrier for any potentially ejected metal.

Although the standoff distance was proactively increased to 150 ft and barriers and shielding used when available, an adequate job hazards analysis/assessment of the risks associated with using the big shear without the natural pile and box barricades that had previously been in place was not completed. Since metal had never travelled greater than 50 ft (15 m) when using the small shear, personnel failed to adequately analyse the potential impacts associated with using a big shear without the natural barricades that approximately 90% of the small shear operations had the advantage of.

Small shear operations were allowed to resume on 8 November 2010. The location, number and use of spotters for the small shears remained the same. The job hazard analysis for small shears indicated that spotters will control the area. This practice of using spotters to control the work zone for small shear operations was reinstituted with reinforced discipline.

The job hazard analysis for large shear operations was red-lined to implement controls for a 300 feet (100 m) stand-off distance and for a grapple operator to be allowed within the zone to bring metal to the Shear Operator, with the stipulation that the demo cage of the grapple will be facing toward the shear during shearing activities. The number of spotters was retained the same for large shear operations, but spotters were relocated at least 300 ft away with the primary purposes of controlling the established 300 ft boundary and assisting the Shear Operator in ensuring that the shear stays within the safe designated operating location and does not encroach into potentially dangerous or unauthorized zones. Shear materials were relocated to the shear itself to maintain the 300 feet boundary.

The facility manager committed to sharing the lessons learned from inadequate review and assessment of the changing conditions in the OSY and the associated failure to evaluate how such changes might impact ongoing and future work. Although the intent of the ongoing remediation activities was to reduce and eliminate the scrap metal in the OSY and was being successfully achieved, it was not adequately acknowledged that the large piles and stacks of boxes were playing a vital role as barriers/shields for the small shear operations. Since elimination of the piles and boxes was the goal of the remediation activities and since the piles and boxes had never been credited as controls, no evaluation was made with regards to how their elimination could impact future operations, such as large shear operations.

Facility managers and project managers will ideally evaluate their ongoing and long-term HAZWOPER remediation activities as changes occur in order to determine if adequate controls remain in place or if additional controls are needed. Successful completion of these activities can result in changing conditions and may render previously implemented controls as inadequate. Assessing how completion of an activity may impact other ongoing or planned activities on a regular basis will allow an opportunity for determination and implementation of any additional controls needed to ensure safe and successful completion of the additional activities.

Lessons learned. Certain remediation activities have a potential to cause hazards to nearby environments and facilities. Adequate hazard assessments will ideally be conducted in this regard.

II–14. SHARING OF INDEPENDENT OVERSIGHT RESOURCES AMONG SITES, PADUCAH AND PORTSMOUTH FACILITIES, USA

Problem encountered. In order to maintain approval to ship waste to the Nevada National Security Site (NNSS), each site is required by the NNSS Waste Acceptance Criteria (NNSS WAC) to have an annual Independent Assessment of their NNSS Waste Certification Program. This assessment verifies compliance with the NNSS WAC Program requirements and has to encompass the entire waste certification programme and supporting elements. In previous years, the required annual Independent Assessment has been performed by a contractor (3 auditors) with vast knowledge of the NNSS WAC requirements and previous Nevada Auditor experience. This is not only expensive but hard to find the skill mix needed to perform an adequate assessment.

In 2011 Paducah evaluated the programme requirements to develop alternate options to third party contractor audits. Exchanging resources with another DOE site with an active NNSS programme was determined to be a viable alternative. Based on follow-on discussions between the Paducah and Portsmouth Waste Certification Officials, the two contractors agreed to exchange resources to conduct Independent Audits on each other's NNSS programmes. A memorandum of agreement between Portsmouth and Paducah was developed and the process for the assessment sharing was started. After the agreement, the contract, and all other applicable documentation were signed by each site and the arrangements were made for the actual assessments.

Paducah assembled a team to perform the Portsmouth assessment in the areas of QA, waste characterization and traceability. The team consisted of a QA Specialist, Waste Engineer and Waste Certification Official (Lead Auditor). Paducah developed a checklist and Audit Plan and submitted it to Portsmouth for approval. Portsmouth provided Paducah with the implementing procedures of their NNSS Waste Certification programme to be reviewed prior to the assessment. Paducah's team went to Portsmouth to perform the on-site portion of the assessment on 27–28 November, 2012. A Draft Assessment report was completed and provided to Portsmouth on 2012-12-20 for review and factual accuracy. The final report was signed and sent to Portsmouth on 2013-01-01.

Portsmouth assembled a team to perform the Paducah assessment in the areas of QA, Waste Characterization and Traceability. The team consisted of a QA Specialist (Lead Auditor), Waste Engineer and Waste Certification Official. Portsmouth developed a checklist and Audit Plan and submitted it to Paducah for approval. Paducah provided Portsmouth with the implementing procedures of their NNSS Waste Certification programme to be reviewed prior to the assessment. Portsmouth's team went to Paducah to perform the on-site portion of the assessment on 18–19 December 2012. A Draft Assessment report was completed and provided to Paducah on 2013-15-01 for review and factual accuracy. Paducah received the final report on 2013-01-29.

The NNSS Waste Certification Program Independent Assessment sharing between Portsmouth and Paducah was not only a cost savings for both sites, but provided a programme improvement learning experience for both teams. Each site's audit team members were very knowledgeable in their respective areas of expertise. The ability to see how another site implements NNSS requirements was invaluable and will promote process improvements and streamlining at both sites [II–15].

Analysis. Utilization of resources currently engaged in implementation of an NNSS Program increases the quality of the audit. Exchanging resources with another site significantly reduces the costs of the audit team and resources to manage site access of visiting personnel. Observing operations at another site provides workers with exposure to alternate programs and processes that may result in identification of improvement opportunities that can be implemented when they return to their home site. When pursuing resource exchanges with other contractors a Memorandum of Agreement is required at a minimum and will ideally be started as early as possible with timely communication updates and coordination with the DOE office.

Lessons learned. To shares resources between facilities and sites provides cost savings and performance improvement opportunities

II–15. LESSONS LEARNED WHEN TRANSFERRING AREAS BETWEEN CONTRACTORS, IDAHO OPERATIONS OFFICE AND IDAHO NATIONAL LABORATORIES

Problem encountered. For a few years decommissioning work was carried out by a DOE-EM (DOE Office of Environmental Management) contractor in a defined and separately controlled decommissioning area located within an operating facility managed by an NE (DOE Office of Nuclear Energy) contractor. Both DOE-EM and DOE-NE are prime contractors to DOE-ID (*Idaho* National Engineering and Environmental Laboratory). The scope of the work included decontamination, demolition and complete removal of highly contaminate reactors, confinement buildings and support structures. After completion of decommissioning work, the area was vacated and turned over to the Facility operated by NE.

Subsequently, some radiologically contaminated debris or soil has been found in areas within or near the previously managed D&D area [II–16].

Analysis. Intercontractor issues emerged regarding adequacy of radiological cleanup, surveys and coordination of turnover of the work-site from the decommissioning contractor to the Facility contractor. Some of the inadequacies included:

- The Interface Agreement for decommissioning work did not contain any details about turnover of the decommissioning area back to the facility operating contractor;
- Coordination between contractors was limited to the following:
  - Informal agreement was reached with the contractor assuming responsibility perform detailed radiological surveys with vacating contractor observing,
  - Receiving contractor performed limited radiological surveys prior to assuming responsibility for the area,
  - A formal turnover meeting was held but the receiving contractor did not attend.
- Surveys performed by the contractor assuming responsibility, beginning about a month following transfer, discovered a number of radioactive particles and contaminated debris in and around the transferred area;
- Difficulty obtaining support from the vacating contractor following the transfer due to project completion and no remaining funding.

Lessons learned:

- More detailed information will ideally be specified in the Interface Agreement on transferring responsibility back to the facility operating contractor;
- Formal transfer agreement between contractors will ideally take place, including a process similar to a readiness review;
- Assuming contractor needs to be more fully engaged in verification of conditions prior to assuming control.

II–16. LESSONS LEARNED FROM V1 NPP DECOMMISSIONING PROJECT, SLOVAKIA

II–16.1. Planning and projects preparation

Lack of detailed characterization of nuclear facility

Issue. Missing Comprehensive Decommissioning database for planning of decontamination processes, dismantling procedures and tools, radiological protection, materials management (radioactive, non-radioactive and hazardous) and decommissioning planning (e.g. planning costs, decide on decommissioning methods, dismantling works planning, manpower, decontamination efforts, waste stream determination, waste management, dose assessment, free release of materials, cost estimation, and other decommissioning activities).

Lessons learned. Site characterization (physical and radiological) is a basic precondition for decommissioning. Analysis of the project based on the plant inventory/characterization is necessary to issue successful dismantling strategy, a consistent plan and a well structured project. Initial characterization has to include estimation of the radioactive, hazardous and other waste amount.

Keep a conservative approach and take into account atypical occurrences of contaminants and hot spots (local emitters, asbestos, oil, other organic compounds) that might have significant impact on the cost of treatment and disposal. The existence of other nuclear facilities at the same site has to be considered in this regard.

Lack of knowledge of precise location of existing utilities

Issue. Missing as-built drawings or precise location of existing utilities (piping, electrical cables) belonging to, or shared with, another facility and the risk of possible damage during execution of works. During civil works can be also find unexpected obstacles in the ground.

Lessons learned. This issue has to be considered during preparation of tender documents and management procedures for notification and solution of unexpected obstacles. During preparation provide review of local documents as carefully as possible performing of excavation, visual inspection and walkdowns, possibly use hand digging. Prior to performing the works switch-off (if possible) electrical power supply in affected areas.

Coordination and interfaces with others decommissioning projects or entities at the site

Issue. The suppliers declare experience in the complexity of multiproject environment and interfaces, in terms of input data, parallel works, requirements, priorities and boundary condition. However, coordination is often difficult because many constraints and outputs from other contracts were delayed or advancing in parallel.

Lessons learned. Keep interfaces between contracts/projects under managerial control. Analyse projects' impacts and interfaces with other projects and activities as soon as possible. Plan implementation of the most difficult projects as early as possible to minimize impact on time, rework, delay, claims/contract amendments.

Knowledge of plant facilities and equipment

Issue. The learning curve of the implementation of a multiproject development had a considerable influence on the project implementation.

Lessons learned. When selecting suppliers, put emphasis on deep knowledge of legislation, procedures and working conditions on the site and design of nuclear facilities. For foreign suppliers it is important to have an experienced local subcontractor to support successful implementation of the project and the overall project team performance. These workers will ideally have more responsibilities and will ideally be more involved in critical tasks where this knowledge is used for the benefit of the project to understand the learning curve and accept it as a necessary parameter of working in an efficient project environment.

Common systems shared at a multifacility site

Issue. Because of the final shutdown of V1 NPP and the following preparation for decommissioning, the Nuclear Regulatory Authority required the segregation of V1 NPP from other nuclear installations and erection of a new independent area nuclear security and protection system. It complies with all legislative requirements to enable the decommissioning of the V1 NPP without any negative influence on other nuclear installations in operation. The common systems in multifacility site have to be adopted to a new situation, e.g. heating and steam distribution system functions, demineralised water, compressed air, compressed nitrogen, decontaminating solutions, wastewater etc.

Lessons learned. To design and implement a new comprehensive plant nuclear security and protection system. To design and implement an optimal configuration of the operating systems of the NPP, the following conditions need to be satisfied:

- The organizations supplying items to the operating consumers (including waste processing) will continue operation after the final shutdown without any interruptions;
- The number of pieces of equipment in operation will be minimized;
- The operating systems configuration and conditions will facilitate the shutdown and decommissioning process;
- Coping with the new operational conditions during shutdown and transition;
- Provide maximal flexibility with regard to the decommissioning process;
- To keep the remaining nuclear facility(ies) in operation without any interruptions;
- Any entity, such as building, turbine hall, etc., will ideally be able to be entirely dismantled without any impact on the other entities of V1.

II–16.2. Licensing activities and contract management

Smooth authority approval process

Issue. Low quality of licensing documents submitted for approval in accordance with the legislative requirements and standards might cause significant delays.

Lessons learned. Develop appropriate communication procedures to ensure that all regulatory bodies and stakeholders are promptly informed of any important information or decision. Maintain effective communications and regular meetings with authorities — on a monthly or quarterly basis. Firmly adhere to a ‘no surprises’ policy as the most important commitment in any licensing process. Follow up the process of legislation amendment and close contacts with authorities. Flexible approach to accommodating changes decreases the costs. Put comprehensive emphasis on the high technical level of licensing documentation.

Experienced and skilled project managers

Issue. Experienced and skilled project managers have a significant impact on contract performance.

Lessons learned. The project manager plays a key role during preparation and implementation of the project. Therefore, it is necessary to pay attention to continuous education, training and motivation.

II–16.3. Dismantling and demolition

Not enough space for execution of decommissioning activities

Issue. Treatment of dismantled material at the place of removal might be difficult due to space constraints, coordination of mass flow, radiation exposure, etc. It is important to precisely specify the interfaces of material flows and rigorous inspection by the customer. The efficiency of waste metal management has an impact on the separate treatment of ferrous and non-ferrous metals.

Lessons learned: Treatment of dismantled material in separate treatment workshop(s). External treatment after dismantling (warm workshop) contributes to continuous and rapid dismantling (no bottlenecks), avoiding spread of contamination, minimization of personnel radiation exposure and project costs.

Central or separate concrete crushing station

Issue. During preparation of demolition projects there was the intention to erect one central crushing station for a large amount of concrete material. The result of assessment in terms of schedule, mass flow, logistics, priorities and interfaces between contracts did not recommend the adoption of this option.

Lessons learned. Provision for crushing concrete and construction waste by a mobile crushing station in each project separately may minimize costs, improve interfaces between separate contractors, decrease demand for coordination, and minimize possible delays.

Vibrations and dust — impact on other nuclear facilities in operation

Issue. Given the proximity of the V2 NPP and Interim Spent Fuel Storage at Bohunice, it was necessary to provide a temporary portable seismic reading device at the boundaries of the site during demolition of cooling towers. The device continuously monitored the vibrations during demolition. The contractor monitored vibration values continuously and ensured that measures were taken to be under the limit for vibrations. With regard to demolition of the cooling towers, the seismic sensors allocated in the interim spent fuel storage cannot record any seismic event exceeding the level of the limits. The same applied for the seismic sensors in the adjacent V2 NPP. For demolition, the contractor was required to take all measures for the elimination of dust production at the site.

Lessons learned. In case that the measured values of vibrations approached the stated limit, the employer was required to immediately stop work, consider the situation and take measures to be below vibration limits. The proposed measures have been approved by the employer. Minimizing the spreading of dust can be achieved during demolition by the water jet method (water screen), which is a standard technique used in combination with a selected method of demolition, or in combination with additional (auxiliary) measures for decreasing dust arisings (catching screens, fencing, etc.). If other methods (measures) are selected, the contractor is required to prepare an assessment that would be the best solution to the problem in view of the nature of the site.

II–16.4. Waste treatment

Flow of material and temporary storage

Issue. Buffer storage and calculation of its capacity play an essential role in smooth decommissioning process.

Lessons learned. Buffer locations are necessary to avoid bottlenecks — early planning is needed for that. For the release of materials from the controlled area it is essential to establish buffer storage locations. Significant attention will ideally be paid to the planning and logistics of the flow of radwaste and the associated costs and resources. It is necessary to standardize packaging slots as a basis for further treatment of the material from decommissioning.

Interim storage of radwaste

Issue. The great advantage of the decommissioning process was the availability of processing and storage capacity of JAVYS before the decommissioning, but just as important was the introduction of a new interim facility for the storage of solid radwaste from the decommissioning of nuclear installations at the Bohunice site. This waste can be released into the environment (decay function of the facility), while radwaste intended for further processing can be disposed of in the Mochovce Disposal facility (buffer function of the facility) since the waste requires safe long-term storage (storage function of the facility).

Lessons learned. Establishment of an interim storage location before decommissioning. Use of decay storage, capacity for dismounting large components and also for the placement of high activated components.

II–17. REMOVAL OF SPENT NUCLEAR FUEL FROM CHORNOBYL NPP UNITS 1–3

The Chornobyl NPP has wide experience in overcoming issues that might significantly complicate implementation of the Chornobyl NPP Units Decommissioning Programme. Usually, decommissioning programmes for nuclear sites last for a long time — up to 15 years in the case of immediate dismantling and more than 50 years for a deferred dismantling strategy. A flexible strategic planning system capable of handling uncertainties over the long term needs to be available for enterprises responsible for decommissioning to identify problems at early stages and respond promptly. Chornobyl NPP's experience in implementing strategic planning considerably improved implementation of the Chornobyl NPP Units Decommissioning Programme.

This annex includes consideration of issues resolved in relation to delayed construction and commissioning of the Interim Spent Fuel Storage Facility (ISF-2) that was expected to be commissioned in 2005. However, ISF-2 construction was interrupted due to non-compliance of the storage facility design with the national technical and safety standards. This resulted in the interruption of the ISF-2 project and, as a consequence, it was impossible to remove spent fuel from Units 1–3. This increased the total time needed to prepare the Chornobyl NPP units for decommissioning and transition to the safe enclosure mode. Problems with the new storage facility would have also a negative impact on the Chornobyl NPP decommissioning strategy. The new situation was unacceptable for Ukraine because of the following reasons:

- Beginning of decommissioning of Units 1–3 would be postponed for 11 years;
- The risk remaining that the ISF-2 commissioning would be delayed;
- Large expenses necessary for supporting safety.

The work strategy was changed promptly to resolve this problem. The decision to transfer SNF from Units 1–3 into the existing (old) 'wet-type' ISF-1 has been made. Significant work on improvement of safety and licensing of this storage facility was performed to implement this option. The result was that the State Nuclear Regulatory Authority of Ukraine issued the permission to use ISF-1 for receiving SNF from Units 1–3 . This work avoided considerable time and financial losses from any delay of ISF-2 commissioning and minimized the impact on the Chornobyl NPP decommissioning process. Consequently, the Chornobyl NPP Units 1–3 decommissioning plan does not depend on the new ISF-2 commissioning dates.

This allowed the release of Unit 1–3 SNF in 2015. Without such a strategic decision the release of the SNF would not be possible before 2020. Thus, financial losses and radiological risks were minimized and planned decommissioning dates maintained.

Lessons learned. The enterprise responsible for decommissioning at the multifacility site will ideally have a strategic planning function. Creation of several planning horizons (current/short term: within a year; prospective: mid-term, up to five years; strategic/long term, more than five years). This allows early detection of problems and their solutions. Development of flexible plans that include alternative scenarios in case of unexpected issues.

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