Measuring and Reporting on Decommissioning Progress

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Introduction

One of the challenges facing AECL, as well as other organizations charged with the responsibility of decommissioning nuclear facilities, is the means by which to measure and report on decommissioning progress to various audiences which, in some cases, may only have a peripheral knowledge or understanding of the complexities associated with the decommissioning process. The reporting and measurement of decommissioning progress is important for a number of reasons, i.e.,

- It provides a vehicle by which to effectively communicate the nature of the decommissioning process;
- It ensures that stakeholders and shareholders are provided with a transparent and understandable means for assessing value for money;
- It provides a means by which to integrate the planning, measurement, and operational aspects of decommissioning

One underlying reason behind the challenge of reporting decommissioning progress lies in the fact that decommissioning programs are generally executed over periods of time that far exceed those generally associated with typical design and build projects. For example, a decommissioning program could take decades to complete in which case progress on the order of a few percent in any one year might be typical. However, such progress may appear low compared to that seen with more typical projects that can be completed in a matter of years.

As a consequence, AECL undertook to develop a system by which to measure decommissioning progress in a straightforward, meaningful, and understandable fashion. The system is not rigorously objective, and there are subjective aspects that are necessitated by the need to keep the system readily understandable. It is also important to note that while the system is simple in concept, there is, nonetheless, significant effort involved in generating and updating the parameters used as input, and in the actual calculations.

Definition of Terms

The following terms play a crucial role in the system that is used to measure decommissioning progress.

Nuclear Facility

The AECL decommissioning program has two fundamental, underlying objectives, i.e.

- To reduce and mitigate the health, safety, and environmental (HSE) risks or actual impacts associated with redundant nuclear facilities
- To reduce and minimize the extent of the financial liabilities associated with redundant nuclear facilities

In the context of the measurement system being described in this paper, the term **nuclear facility** is broader than just a structure and the associated nuclear equipment, or a nuclear installation, and includes radioactive wastes as well as areas of contamination that may have directly or indirectly resulted from nuclear operations.

Nuclear Liability

To an increasing extent, there has been a recognition that the costs of decommissioning redundant nuclear facilities must also take into account the costs of support programs as well as of "enabling" facilities, i.e., those new facilities that must be developed and built in order to execute the decommissioning process. These enabling facilities might include storage, processing, or disposal facilities, and the support programs would include such areas as quality assurance, radiation protection, environmental monitoring, operational experience, security, site infrastructure etc. The redundant nuclear facilities taken together with the required enabling facilities and support programs are defined as the **nuclear liability**.

Risk Reduction Measure

The **Risk Reduction Measure** is one of the key parameters used in measuring decommissioning progress, and conveys the extent to which the **risk level** associated with a nuclear liability has been lowered. It can be used for individual nuclear facilities as well as for the collection of facilities, wastes, enabling facilities, etc that comprise the entire nuclear liability.

The **risk level** is defined as follows:

Risk Level = (Decommissioning Cost)(Weighting Factors based on Nuclear Liability Characteristics)

The reasoning behind this definition of risk level is based on the premise that the greater the cost to decommission a nuclear liability, the higher are the associated HSE risks, e.g., a reactor vs shielded facilities. Similarly, some facilities have intrinsically more risks

associated with them than others, e.g., a reactor vs a cafeteria, and hence the use of the weighting factors. Details as to the nature of the weighting factors that are used by AECL are provided later in the paper.

To calculate the Risk Reduction Measure requires defining a set of **decommissioning activities,** i.e**.,** those activities that must be completed in order to drive the HSE risks to the desired level. AECL has developed a set of generic activities that can be applied to a broad suite of nuclear liabilities. As these activities are completed, risk level "points" are accumulated which can then be compared to the total number of risk points associated with individual or overall risk levels

RRM= ? Risk Level/Total Risk Level

where ? Risk Level is based on the number and type of decommissioning activities completed.

Liability Reduction Measure

The Liability Reduction Measure conveys the extent to which the **liability level** associated with a nuclear liability has been lowered.

The **liability level** is simply the total spend required to fully disposition the nuclear liability.

To calculate the Liability Reduction Measure also requires defining the series of **decommissioning activities** that must be completed in order to totally discharge the financial liabilities associated with the nuclear liabilities. As these activities are completed, the associated costs are accumulated which can then be compared to the total liability level.

LRM= ? Liability Level/Total Liability Level

In most cases the activities required to effect a risk reduction are also those required to bring about a reduction in the liability level, but the converse is not always true. For example, some monitoring and maintenance activities may be part of the total cost of decommissioning a facility, but may not contribute substantially to risk reduction (just risk control).

Decommissioning Stages and Decommissioning Activities

From the above discussion, it is clear that the ability to calculate the RRM and the LRM is entirely dependent upon the ability to identify a series of decommissioning activities that accurately portray what needs to be done in order to reduce both risk and liability to target levels.

To this end, AECL has developed a system that measures decommissioning progress against five **decommissioning stages** that logically and intuitively describe the stages involved in decommissioning. Those five stages are defined as follows:

- Initiate: The redundant facility is placed into a safe shutdown state by the operational organization, and the facility is formally transferred to the decommissioning authority.
- Define: The hazards, risks, and characteristics of the redundant facility are assessed, together with the decommissioning costs and waste volumes.
- Enable: The steps required to allow actual physical decommissioning to take place are completed. These steps would include securing both the necessary regulatory approvals as well as the required resources (funding, facilities, and staff)
- Mitigate: Activities are executed to address the immediate health, safety, and environmental impacts associated with the redundant facilities, or to reduce the probability of an event that could have adverse effects on health, safety, or the environment
- Achieve Endstate: All remaining decommissioning activities are completed.

For each of these decommissioning stages there is a series of **decommissioning activities.** In many respects, the decommissioning activities are analogous to the activities that represent the work breakdown structure for a project. The list of decommissioning activities developed by AECL is quite extensive, but some of the more important ones are included in the table below.

STAGE	DECOMMISSIONING ACTIVITIES
Initiate	Operational Organization Vacate the Structure
	Achieve Safe Shutdown State (SSS)
	Operational Organization Formally Turns the Facility Over to the Decommissioning Authority
Define	Perform Systems Condition Assessment of Facility
	Characterize Facility (radiological hazards, hazardous materials)
	Prepare Cost Estimates
	Prepare Waste Estimates
	Locate, Gather, Catalog, Archive, and Assess Historical Information
	Perform Environmental Monitoring
	Perform Field Inspections
Enable	Obtain Regulatory Approvals
	Secure Required Resources (funding, staffing)
	Implement Support Systems (QA, RP, Operational Experience (OPEX), Waste Management)
	Develop Required “Enabling” Facilities
Mitigate	Achieve Safe Sustainable Shutdown State (SSSS)
	Remove/Contain/Stabilize/Isolate Sources of Contamination
	Enhance Systems
	Implement Storage with Surveillance
Achieve Endstate	Demolish Structure
	Have In-Situ Disposal Case Accepted
	Place Waste in Disposal Facility

Operational Deliverables

Each decommissioning activity may in turn comprise a series of **operational deliverables,** which can form the basis for annual or short term operational plans. Again, relative to a project work breakdown structure, the operational deliverables would represent lower tier tasks. Generally, operational deliverables are quite detailed and facility specific. For example, the decommissioning activity "Develop Required Enabling Facilities" may in fact be a very major project requiring years to complete. In such a case, there will be detailed plans and objectives, as well as measurement parameters, associated with that project. Similarly, obtaining regulatory approvals could mean the preparation of numerous documents with multiple approval steps and also include such items as the completion of a public consultation process. Thus there is a cascade from decommissioning stages to decommissioning activities to operational deliverables, with the latter being the primary driver of day-to-day activities.

Weighting Factors

It was clear from the start of the development of this system that in terms of risk reduction (i) some decommissioning activities would be more effective in reducing HSE risks than others, and (ii) some types of buildings and nuclear installations had inherently higher potential impacts on HSE than others. To address this fact, two weighting factors were developed; the first (activity weighting factor) was intended to indicate the relative importance of the decommissioning activities in reducing HSE risks, while the second (building weighting factor) was intended to indicate the HSE implications associated with building types. To this end, buildings were placed into 4 major categories:

- Nuclear facilities listed on the site license
- Radioactive laboratories and other buildings where radioactive materials have been or are being handled
- Low-hazard nuclear structures
- Uncontaminated buildings

Calculation of the Risk Reduction Measure (RRM) and Liability Reduction Measure (LRM)

The primary measures being used in the AECL decommissioning program to assess progress are the Risk Reduction Measure (RRM) and the Liability Reduction Measure (LRM). Using the parameters discussed above, the process of actually calculating the RRM and LRM involves the following steps:

- A comprehensive list of the specific components that comprise the **nuclear liability** is prepared. As noted above, this list potentially includes
    - nuclear structures - reactors, shielded facilities, laboratories, etc
    - waste management areas – facilities to store and dispose of radioactive wastes
    - radioactive waste – the wastes being stored

  - contaminated lands – resulting from nuclear activities
  - contaminated groundwater
  - enabling facilities – storage, processing, and disposal facilities
  - support programs – RP, QA, security, etc
- The **decommissioning activities** that will need to be completed in order to fully discharge the nuclear liabilities are identified. These activities can be further subdivided into **operational deliverables,** which can be incorporated into annual plans or short term plans and monitored accordingly.
- Using the decommissioning activities and operational deliverables, estimates are developed for the costs associated with discharging the various nuclear liabilities. This process is clearly not trivial, particularly for a large site such as that associated with the Chalk River Laboratories, and must also recognize the uncertainties surrounding the long-term nature of the decommissioning process. These costs, taken in total, then define the **liability level,** and the units associated with the liability level are dollars.
- Those decommissioning activities and operational deliverables, which specifically contribute to reducing the HSE risks or to mitigating the HSE impacts, are then specifically identified. While the majority of the decommissioning activities will reduce both the liability level and the risk level, some activities that lower the liability level may not be particularly effective in reducing HSE risks, e.g., paying the taxes and utilities associated with a redundant nuclear facility. Similarly, the activities associated with maintaining a redundant nuclear facility in a shutdown state will control, but not reduce HSE risks to nearly the same extent as activities that actually result in the decontamination and demolition of that structure.
- Weighting factors are then assigned to those activities that contribute to the reduction of risk. In many respects, this is the most subjective component of this process, particularly with respect to the value of those weighting factors. However, the purpose of the RRM and the LRM is to communicate progress in a reasonable and understandable fashion, and so as long as the weighting factors have been developed by experts with a good knowledge of the nature of the facilities undergoing decommissioning, and the weighting factors are applied in a consistent fashion, then that objective is met.
- The product of the various weighting factors for a given nuclear liability and the associated liability level (in $s) for that liability give the **risk level**, and the units for risk level are weighted dollars or risk “points”.

The following two tables demonstrate the process, and in this particular example, the process is applied to two different types of buildings, one being a nuclear facility listed on the site license, the other being an uncontaminated building. For a case such as the CRL site, there would be on the order of hundreds of such entries in order to totally cover the nuclear liability. Therefore, as previously noted, while the concept behind the RRM and the LRM is straightforward, the implementation process can be complex.

Liability Levels and Risk Levels Prior to Start of Decommissioning Process

	Bldg 1 Nuclear Facility on Site License		**Bldg 2** Uncontaminated Building		Total Program
Decommissioning Activities	Decommissioning Cost ($M)	Activity Weighting Factor	Decommissioning Cost ($M)	Activity Weighting Factor	
INITIATE					
Achieve SSS	5	5	1	5	
DEFINE					
Characterize Bldg	1	1	0.2	1	
Assess Bldg Systems	1	5	0.3	5	
ENABLE					
Secure Regulatory Approvals	3	5	0.1	0	
Develop Required Enabling Facilities	100	10	0	0	
MITIGATE					
Achieve SSSS	5	5	1	5	
Perform Storage with Surveillance	20	0	5	0	
ACHIEVE ENDSTATE					
Demolish	5	5	5	5	
Dispose of Waste	15	5	1	0	
TOTAL Cost (a)	$155M	41	$13.6	21	
TOTAL Activity Weighting Factors (b)	41		21		
Building Weighting Factor (c)	4		1		
Risk Level for Bldg =(a)(b)(c)	25420		286		25706
Liability Level for Bldg =(a)	$155M		$13.6		$168.6

Liability Levels and Risk Levels Following Progress on Decommissioning

	Bldg 1 Nuclear Facility on Site License		**Bldg 2** Uncontaminated Building		Total Program
Decommissioning Activities	Decommissioning Cost ($M)	Activity Weighting Factor	Decommissioning Cost ($M)	Activity Weighting Factor	
INITIATE					
Achieve SSS					
DEFINE					
Characterize Bldg					
Assess Bldg Systems					
ENABLE					
Secure Regulatory Approvals					
Develop Required Enabling Facilities	100	10			
MITIGATE					
Achieve SSSS	5	5			
Perform Storage with Surveillance	20	0	5	0	
ACHIEVE ENDSTATE					
Demolish	5	5	5	5	
Dispose of Waste	15	5	1	0	
TOTAL Cost (a)	$145M		$11M		
TOTAL Activity Weighting Factors (b)	25		5		
Building Weighting Factor (c)	4		1		
Risk Level for Bldg =(a)(b)(c)	14500		55		14555
Liability Level for Bldg =(a)	$145M		$11M		$156M

As each decommissioning activity is completed, both risk level reduction "points" and liability dollars are set to zero.

Progress is then simply the reduction in liability and risk levels relative to the total values.

For example, in the case above

Building 1

LRM = ($155M - $145M)/$155M
LRM = 0.064

RRM = (25420-14500)/25420
RRM = 0.43

Building 2

LRM = ($13.6M - $11M)/$13.6M
LRM = 0.19

RRM = (286 – 55)/286
RRM = 0.81

Total Program

LRM = ($168.6M - $156M)/$168.6M
LRM = 0.074

RRM = (25706 – 14555)/25706
RRM = 0.43

Conclusions

A methodology has been developed that provides a means by which to monitor decommissioning progress that (i) is intuitively understandable, (ii) conveys a model of the decommissioning process, and (iii) can be directly integrated into operational planning.

The system does contain elements of subjectivity, most notably in the assignment of weighting factors, but as long as those assignments are performed by knowledgeable staff, and the weighting factors are applied in a consistent fashion, the values of RRM and LRM provide good insight into decommissioning progress.

The system reveals a very important tenet, i.e., in deciding which decommissioning activities should be executed, there needs to be an *a priori* decision made as to whether the focus of the activities should be on reducing HSE risks, or on reducing financial liabilities.

The magnitude of the RRM and LRM may seem small relative to measures of progress typically seen with, for example, design and build projects. This fact may need to be explained to stakeholders and shareholders to whom these parameters are communicated.