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Supplement to a Methodology for Succession Planning for Technical Experts

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OAK RIDGE NATIONAL LABORATORY
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Nuclear Security and Isotope Technology Division

SUPPLEMENT TO A METHODOLOGY FOR SUCCESSION PLANNING FOR TECHNICAL EXPERTS

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CONTENTS

LIST OF TABLES

ACRONYMS

ASME	American Society for Mechanical Engineers
DOE	US Department of Energy
HFIR	High Flux Isotope Reactor
HR	Human Resources
IAEA	International Atomic Energy Agency
INMM	Institute of Nuclear Materials Management
ISI	In Service Inspection
ISOCS	In Situ Object Counting System
NDA	nondestructive assay
NNSA	National Nuclear Security Administration
ORNL	Oak Ridge National Laboratory
R&D	research and development
RELAP	Reactor Excursion and Leak Analysis Program
SAR	Safety Analysis Report
SME	subject matter expert
TSR	Technical Safety Requirements
TVA	Tennessee Valley Authority
USQD	Unreviewed Safety Question Determination
Y-12	DOE/NNSA National Security Complex

EXECUTIVE SUMMARY

This report complements A Methodology for Succession Planning for Technical Experts (Ron Cain, Shaheen Dewji, Carla Agreda, Bernadette Kirk, July 2017), which describes a draft methodology for identifying and evaluating the loss of key technical skills at nuclear operations facilities. This report targets the methodology for identifying critical skills, and the methodology is tested through interviews with selected subject matter experts.

1. INTRODUCTION

1.1 PURPOSE OF THE INTERVIEWS

A methodology for identifying critical skills in nuclear operations facilities was proposed in a 2017 Oak Ridge National Laboratory (ORNL) report (Ron Cain, Shaheen Dewji, Carla Agreda, Bernadette Kirk, July 2017). In this report, the methodology is tested through personal interviews of subject matter experts (SMEs), who were identified as key personnel by their management.

The purpose of the interviews is to identify the critical skills of the SMEs and rank them according to a position risk factor. The ranking analysis will then enable an institution to implement a succession plan based on the potential loss of the SMEs.

1.2 SCOPE

Interviews focused on SMEs at the High Flux Isotope Reactor (HFIR) at ORNL. A second set of interviews focused on nuclear safeguards SMEs.

HFIR is an 85 MW reactor built in the 1960s, initially to study transuranic isotopes (Murray W. Rosenthal, 2010). Its fuel is highly enriched ^{235}U. Today, HFIR's scope includes materials irradiation, neutron activation, and neutron scattering.

We chose HFIR because it is an established facility where the experts have specific jobs that are well-defined and needed for longevity. The interviews of HFIR SMEs helped in refining the questions to identify critical skills (Appendix A). Given this experience, our next step was to interview nuclear safeguards SMEs working in research and development (R&D) groups. In the R&D groups, critical job skills were dictated not only by the needs of ORNL but also by the changing programmatic direction of the National Nuclear Security Administration's (NNSA).

Section 2 presents a review of the critical skills methodology and the International Atomic Energy Agency (IAEA) position risk factor. Sections 3–4 cover the respective interviews of the SMEs.

2. REVIEW OF CRITICAL SKILLS METHODOLOGY

2.1 METHODOLOGY

We have devised a six-step methodology for identifying critical skills for SMEs at nuclear facilities. The methodology is taken from the report by Cain et al. (2017). It is imperative to include a Human Resources (HR) staff member in following the methodology because of HR's familiarity with the organization's structure and job classifications.

1. Select a nuclear facility or group of experts at a Department of Energy (DOE) national laboratory
2. Select candidates
3. Interview candidates
4. Analyze interview results
5. Validate critical skills and level of criticality
6. Assess potentially critical skills by listing and ranking them using the IAEA position risk factor scale of 1–5

Each of the steps above will be described, in order, in the following subsections.

2.1.1 Select a Nuclear Facility or Expert Group of Individuals at a DOE National Laboratory

The facility or group must be integral to DOE's mission and must have been in operation for several years. Because it serves DOE's mission, experts must have worked in the facility or group for a considerable amount of time.

2.1.2 Select Candidates

The manager of the facility or group aids in identifying individuals who have the desired critical skills needed to perform their jobs. Criteria can include how the loss of an employee would have a significant impact on the organization; the minimum number of employees required for operation; employee job titles and job positions; and the number of employees eligible to retire. Individuals and positions vital to laboratory operation should be considered.

The following steps are recommended to identify critical SMEs at nuclear facilities:

- Meet with facility or group manager and operations managers to identify individuals with critical skills in their respective areas.

- Interview operations managers to determine the individual(s) whose departure(s) would negatively impact the organization. Obtain the job titles and job descriptions for these individuals. If there are many individuals identified, and a job title is shared by more than one individual, ask the manager to categorize the job importance of those individuals based on the impact of losing him or her on short notice.

- Validate the names of those deemed most critical by reviewing the skills list with the manager.

2.1.3 Interview Process

The interview process involves a prepared questionnaire (Appendix A) and at least two interviewers—one asking questions and the other recording the session and possibly employing a recording device. One of the interviewers should have technical knowledge or familiarity with the expert's field. The questionnaire will be reviewed by the manager and then sent to the potential interviewee/expert before the session. The interviewee is informed by their manager of the purpose of the interview and its importance. The potential interviewee/expert completes the form and returns it to the interviewers. Once the interviewers receive a copy of the completed questionnaire and have a chance to digest the input, a date is set for the follow-up face-to-face session. The follow-up interview occurs in a quiet place. After the interview session is over, the interviewers provide a summary of the interview to the interviewee. The summary is vetted by the interviewed expert to ensure that no errors were made in the transcription.

2.1.4 Analyze Interview Results

The analysis is designed to determine potentially critical skills. The interviewers take the notes from the interview and analyze the information to extract critical skills for each interviewee. The interviewers, with the aid of the facility manager, then review the questionnaires and interview transcripts to prepare a list of skills. A table of critical skills for each interviewee can then be compiled.

2.1.5 Validate Critical Skills and Level of Criticality

Validating critical skills and their level of criticality is performed by the manager, the interviewers, and possibly a resident expert who is familiar with the interviewee's functions. The manager ensures the critical skills are aligned with the organization’s mission. The interviewers share their analysis with the manager, operations managers, or both to validate the criticality of the skills identified and to ascertain the level of criticality of each skill and individual. The relevant job descriptions for the interviewees also play a crucial role in validating critical skills. The agreed-upon level of criticality is included in the analysis as a spreadsheet.

2.1.6 Assess Potentially Critical Skills

As a final output, the assessment features a table of skills with a level of criticality defined for each skill. The interviewers complete the table with results from the interviews and provide the output to the facility or group manager and the operations managers, who can then proceed to plan for knowledge retention for key critical skills.

2.2 IAEA POSITION RISK FACTOR

The output from each interview, together with the job description, is summarized in a table with the critical skills listed first. Each skill is ranked from 1 to 5, using IAEA’s position risk factor criteria (IAEA, 2006). We have interpreted the IAEA ranking below.

5 Most critical, no replacement readily available, lack of documentation for tacit knowledge

4 Critical, few available replacements, some documentation of tacit knowledge

3 Critical, replacements available, documentation of tacit knowledge exists

2 Not mission critical, recruits trainable in a year

1 Least critical, replacement through external hires

We use the IAEA ranking in the next section to identify critical skills. For clarity, tacit knowledge resides in individuals and is difficult to document (IAEA Nuclear Energy Series, 2011).

3. TRIAL RUN OF THE METHODOLOGY

3.1 SELECTION OF NUCLEAR FACILITY AND CANDIDATES, INTERVIEW PROCESS AND ANALYSIS

The first step in the methodology is the selection of the HFIR nuclear facility and nuclear safeguards groups (Step 2.1.1). Seven SMEs were selected (Step 2.1.2) with the help of HR and management. From HFIR, a senior systems engineer, two senior nuclear safety analysts, and a senior inspection engineer were selected. From the safeguards groups, two nuclear engineers and a group leader were selected. The interview results for the seven SMEs (Steps 2.1.3 and 2.1.4) are described below.

3.1.1 HFIR INTERVIEWS

3.1.1.1 Senior Systems Engineer (SME A)

The interviewee will be referred to as SME A. SME A is a senior systems engineer with a background in civil engineering and has worked at HFIR for about 10 years. She has past industry experience in small motor design.

Her primary function at HFIR involves troubleshooting motors. All issues involving motors are referred to her. If a new motor is needed, she writes the specifications and makes purchasing recommendations.

She informs staff what needs to be done to fix motor-related issues because she has been a motor designer. She also advises the craft workers on how to perform tasks because she is not allowed to do hands-on work. In addition, she handles battery systems and general electrical design and upgrade of motors. She keeps track of the maintenance of all motors.

SME A had to attend the required training at HFIR, which involves both systems and work packaging training. She communicates and reaches out to other experts at HFIR who have had years of nuclear experience.

For resources, SME A refers to in-house written procedures, HFIR drawing and work package databases, and the Electric Power Research Institute publications on motors, the Master Equipment List, and manuals from vendors. HFIR has extensive online databases that can be easily accessed by those who need them.

SME A has skills that are key to HFIR operations. Should she leave the organization, skills that need replacement involve: motor design (i.e., why motors are built a certain way and how they are built), motor inventory, motor maintenance, and motor procurement. According to SME A, it would take about a year of on the job training for someone to replace her. The individual would need a background in engineering, specifically motors. Past nuclear plant experience would also be complementary.

The capture of her knowledge or skills is accomplished through interactions with staff who watch her perform motor troubleshooting. The HFIR online databases provide extensive information and are kept current. All work packages are documented in detail.

To keep up with technology, SME A attends conferences and is a member of the Institute of Electrical and Electronics Engineers.

Table 1 depicts the critical skills for SME A and includes supervisor feedback.

Table 1. Critical skills for HFIR senior engineer—Systems engineer (SME A)

Critical skills for experienced engineer—HFIR senior systems engineer	1	2	3	4	5
Performs independently in a specialty area (motors) and actively imparts knowledge to others					✓
Plans and coordinates programs and large-scale engineering projects			✓		
Acts as a technical specialist for a specific engineering field (motors)					✓
Carries out advanced engineering and technical tasks				✓	
Performs independent research and reviews, studies and analyses of motors in support of technical projects				✓	
Performs risk assessments and generates creative solutions to work situations (troubleshoot motors)				✓	
Provides in-depth technical expertise to develop, manage, and implement engineering activities related to plant safety, reliability, maintainability and availability				✓	
Maintains high personal standards of performance, responsibility and professionalism	✓				
Ability to respond to a nuclear emergency				✓	
Availability to attend required training and certification	✓				
Ability to communicate with other staff	✓				
Ability to accept criticism	✓				
Ability to face a difficult situation			✓		
Ability to face constant time pressure			✓		
Critical thinking (motors)					✓
Complex problem solving (motors)					✓
Judgment and decision-making (motors)					✓
Active listening	✓				
Computer skills	✓				
Ability to make presentations to management to summarize complex technical issues, enabling management to arrive at the correct decision				✓	
Interface with regulators about systems operability, problem identification, and compliant solutions				✓	

3.1.1.2 Senior Engineer, Nuclear Safety Analyst (SME B)

SME B is a senior systems engineer with a background in nuclear engineering and has worked at HFIR for about 25 years. He has years of experience as a nuclear safety engineer at the power plants run by the Tennessee Valley Authority (TVA) and was also involved briefly with quality assurance at the Y-12 National Security Complex prior to joining HFIR.

SME B is a nuclear safety analyst at HFIR. He writes Unreviewed Safety Question Determination (USQD) documents and has produced about 1,800 over his time at HFIR. As an operating nuclear facility, every change at HFIR has to be evaluated to see if it will alter the safety basis for the facility. This process involves writing a USQD. USQDs will range from 3–4 paragraphs to 8–10 pages. SME B also reviews USQDs for other staff, and they learn from his feedback. SME B has the additional responsibility of stopping work if there is a nuclear safety issue.

SME B attended the reactor operator training at HFIR. This training is not required for a safety analyst but provides a deeper perspective into the nuclear safety of the reactor.

While at TVA, SME B developed a document for the Watts Barr plant called a Q list. The list included all the safety equipment and consisted of about 55,000 items. The TVA experience was useful in coming to HFIR. HFIR had been looking for someone with safety analysis experience. SME B's knowledge of the nuclear safety culture was a plus when he was hired by HFIR.

For resources, SME B refers to previous USQDs, Safety Analysis Reports (SAR), in-house written procedures, and HFIR drawings and work package databases.

SME B's specialty lies in the documentation of the USQDs and Technical Safety Requirements (TSR). Most of his special tasks require a detailed, methodical approach. He put together the detailed list of every piece of equipment in the plant. He had to be familiar with the safety basis report, engineering drawings, and general operations. He also writes the TSRs, which have to be updated annually. When the cold source was installed at HFIR, he wrote a supplement to the overall TSR that covered the addition.

The capture of his knowledge or skills is accomplished through reviews of USQDs. SME B marks up reviews and gives feedback on wording to the staff. He feels comfortable leaving the organization because there are staff who have been at the HFIR for some time, who can share their knowledge with new staff. There are about six people who write 99% of the USQDs. Most of them have been at HFIR for at least 5 years and are highly familiar with USQDs. Becoming proficient in writing USQDs is estimated to take at least 1 year to 18 months. One would need to become familiar with HFIR and the safety analysis reports. For someone who is newly out of college, it might take longer.

Based on the interview alone, Table 2 depicts the critical skills for SME B. Feedback from the immediate supervisor was not received.

Table 2. Critical skills for HFIR senior engineer—Nuclear safety analyst (SME B)

Critical skills for experienced engineer—HFIR safety analyst	1	2	3	4	5
Performs independently in a specialty area (nuclear safety) and actively imparts knowledge to others					✓
Plans and coordinates programs and large-scale engineering projects				✓	
Acts as a technical specialist for a specific engineering field (SARs)					✓
Carries out advanced engineering and technical tasks					✓
Performs independent research and reviews, studies, and analyses in support of technical projects (USQD)					✓
Generates creative solutions to work situations (USQD)					✓
Provides in-depth technical expertise to develop, manage, and implement engineering activities related to plant safety, reliability, maintainability, and availability					✓
Maintains high personal standards of performance, responsibility, and professionalism					✓
Ability to respond to a nuclear emergency					✓
Availability to attend required training and certification	✓				
Ability to communicate with other staff	✓				
Ability to accept criticism	✓				
Ability to face difficult situations					✓
Ability to face constant time pressure				✓	
Critical thinking (HFIR work packages, SARS, and USQDs)					✓
Complex problem solving (nuclear safety)					✓
Judgment and decision-making (nuclear safety)					✓
Active listening	✓				
Computer skills	✓				
Ability to write work packages, documentation, USQDs, and SARs					✓

3.1.1.3 Senior Engineer, Nuclear Safety Analyst (SME C)

SME C is a senior systems engineer with a background in mechanical engineering and has worked at HFIR for a little less than 20 years. His background is in thermal fluid flow and has afforded him the opportunity to work with transient analysis. His specialty is the severe accident computer code Reactor Excursion and Leak Analysis Program (RELAP). He had prior experience with this type of code at the Nuclear Regulatory Commission.

As a nuclear safety analyst, SME C is in charge of the continuous modeling and simulation of the HFIR reactor using the RELAP code. RELAP calculates fluid and thermal conditions of HFIR and ensures that it operates within established safely parameters. There is only one other HFIR staff member familiar with RELAP.

SME C was required to take a week-long workshop on RELAP prior to beginning his role as software analyst. He continued to educate himself on the computer code after the workshop. He also attended the reactor operator training to familiarize himself with HFIR operations.

SME C works closely with other staff, some of them acting as mentors. His work has to be validated by others to ensure reactor safety. The RELAP analysis is integrated into the HFIR SAR. SME C also works on USQDs and interacts with other safety analysts.

RELAP is SME C's main area of expertise. His knowledge of RELAP is the most important for succession planning purposes. He has been maintaining and updating a RELAP model of HFIR for many years.

SME C's type of work includes a significant amount of crisis management. Working in an operational facility is a challenge because deadlines must be met. Staff members are often called on to do work they may not have done before.

Key resources used by SME C include SAR documents, safety-related equipment lists, safety specifications, and USQDs. All of these are available online.

For knowledge capture, a paper trail is always created. This includes documentation of any change or upgrade to the code and software quality assurance. Computer files and calculations are preserved. Everything is saved to an archive copy.

Should SME C leave, it would take a year or more to bring the replacement up to date on the RELAP model of HFIR. Since much of the knowledge is HFIR-specific, the individual would need to be educated on how the reactor operates, and he or she would also need a mechanical or nuclear engineering background. Experience at a DOE facility is a plus.

SME C is a member of the American Society for Mechanical Engineers (ASME).

Based on the interview alone, Table 3 depicts the critical skills for SME C. Feedback from his immediate supervisor was not received.

Table 3. Critical skills for HFIR senior engineer—Nuclear safety analyst (SME C)

Critical skills for experienced engineer—HFIR nuclear safety analyst (Software)	1	2	3	4	5
Performs independently in a specialty area (severe accident software) and actively imparts knowledge to others					✓
Plans and coordinates programs and large-scale engineering projects			✓		
Acts as a technical specialist for a specific engineering field (use of RELAP severe accident software)					✓
Carries out advanced engineering and technical tasks					✓
Performs independent research and reviews, studies and analyses in support of technical projects (RELAP analysis)					✓
Generates creative solutions to work situations (troubleshoot software)					✓
Provides in-depth technical expertise to develop, manage and implement engineering activities related to plant safety, reliability, maintainability and availability					✓
Maintains high personal standards of performance, responsibility and professionalism					✓
Ability to respond to a nuclear emergency (apply RELAP to severe accidents)					✓
Availability to attend required training and certification	✓				
Ability to communicate with other staff	✓				
Ability to accept criticism	✓				
Ability to face a difficult situation					✓
Ability to face constant time pressure				✓	
Critical thinking (RELAP software troubleshoot)					✓
Complex problem solving (RELAP troubleshoot)					✓
Judgment and decision-making (software analysis)					✓
Active listening	✓				
Computer skills	✓				

3.1.1.4 Senior Inspection Engineer (SME D)

SME D is a senior systems engineer with a background in mechanical engineering and has worked at the HFIR for about 15 years. He is an In-Service Inspection (ISI) program manager. He has past experience in nuclear power plants across the country. Because of his extensive experience in inspection and surveillance at nuclear plants, he was hired at HFIR. Besides being an ISI manager, he is an expert on pressure relief devices and pipe fabrication and welding. He is the primary coolant system engineer and pressure vessel program contact at HFIR.

SME D's training includes courses in ISI offered by ASME. He has also taken courses in nondestructive examination. He received system engineering, task leader, and USQD training at HFIR to prepare for his inspection work.

As an ISI expert, SME D led the rewrite of the entire HFIR ISI program. The previous version was difficult to follow, and it was difficult to determine HFIR compliance. The revised program is easier to read and shows all necessary inspections. It is also easier to comply with because every step is better tracked electronically.

SME D used to subscribe to the ASME magazine, but it is no longer relevant to his work. Instead he refers to the systems engineering training book that includes required reading. In addition, he refers to the ASME Section 11 as it relates to ISI, ASME B31-1 for piping and ASME Section 8 for pressure relief valves.

SME D's expertise includes piping modifications, pressure relief valves and pressure leak testing of components of the HFIR. He is the principal contact for piping troubleshooting. He is very familiar with the ASME codes, so his expertise is needed with HFIR piping projects. He works with other engineers to perform piping analysis to ensure HFIR meets compliance requirements.

There is a procedure to capture vital inspection-related information. All information is documented and available for easy computer access. Particularly, the repetitive maintenance process has the tasks documented and stored on a computer.

If SME D had to leave HFIR, a new hire would have to learn the ISI process, which may not take long. Assuming the role of the primary coolant system engineer would take about 2 years. A new graduate would need considerable time to learn all of the procedures. Commercial nuclear power plant experience is highly favorable.

Based on the interview alone, Table 4 depicts the critical skills for SME D. Feedback from his immediate supervisor was not received.

Table 4. Critical skills for HFIR senior engineer—Inspection engineer (SME D)

Critical skills for experienced engineer—HFIR In Service Inspection (ISI) manager	1	2	3	4	5
Performs independently in a specialty area (systems inspection) and actively imparts knowledge to others					✓
Plans and coordinates programs and large-scale engineering projects (ISI)					✓
Acts as a technical specialist for a specific engineering field (ISI)					✓
Carries out advanced engineering and technical tasks					✓
Performs independent research and reviews, studies, and analyses in support of technical projects					✓
Generates creative solutions to work situations (troubleshoot inspection)					✓
Provides in-depth technical expertise to develop, manage, and implement engineering activities related to plant safety, reliability, maintainability, and availability					✓
Maintains high personal standards of performance, responsibility, and professionalism					✓
Ability to respond to a nuclear emergency					✓
Availability to attend required training and certification	✓				
Ability to communicate with other staff	✓				
Ability to accept criticism	✓				
Ability to face a difficult situation					✓
Ability to face constant time pressure				✓	
Critical thinking (inspection)					✓
Complex problem solving (inspection)					✓
Judgment and decision-making (inspection)					✓
Active listening	✓				
Computer skills	✓				

3.1.2 INTERVIEWS OF SAFEGUARDS SUBJECT MATTER EXPERTS

3.1.2.1 Safeguards Expert (SME E)

SME E is a R&D staff member with a background in nuclear engineering and has worked at ORNL in the safeguards group for 9 years. She spent internships at Lawrence Livermore and Los Alamos National Laboratories while in school and was exposed to nuclear safeguards during those appointments. She is currently finishing her PhD in nuclear engineering while working at ORNL and expects to graduate in 2017.

As a nondestructive assay (NDA) research engineer, SME E develops detectors for safeguards applications. She helps train NDA staff from other institutions and participates in nonproliferation workshops for university students. She also manages a few small projects. She interfaces with the International Nuclear Safeguards Engagement Program partner countries, such as South Africa, and designs some of the training. She is a material balance accounting representative and works on other nuclear materials projects. SME E performs measurements involving uranium standards.

As an R&D engineer, staff members seek out SME E's expertise in maintenance troubleshooting, data analysis, and interpretation of detectors. She is an expert Monte Carlo Neutral Particle computer code user and is very proficient in modeling detectors.

SME E's group does not have a formal process to capture knowledge and data. They have a group SharePoint where they store presentations but with no version control. Pacific Northwest National Laboratory maintains most of the training materials.

SME E's current work is research-related so she needs to keep current with what is published. She reads *Nuclear Instruments and Methods in Physics Research Section A*, Institute for Nuclear Material Management (INMM) journals, and IAEA publications.

ORNL resources that aid SME E in performing her job include computing clusters and readily accessible software through the Radiation Safety Information Computational Center. ORNL also has available NDA systems.

SME E's other responsibilities are as lab space manager, material balance accounting representative, and manager of the majority of training.

If SME E leaves the organization, it will take 1–2 years of training for someone to assume her role. It took her 5 years to learn all the systems and how to use them efficiently. The replacement would need to have a technical, physics-based nuclear engineering background or be an electrical engineer with a nuclear background. SME E is a member of INMM.

Based on the interview and input from SME E and her immediate supervisor, Table 5 depicts the critical skills for SME E.

Table 5. Critical skills for safeguards—R&D nuclear engineer (SME E)

Critical skills for safeguards SME—R&D nuclear engineer	1	2	3	4	5
Performs independently in a specialty area (NDA and detectors) and actively imparts knowledge to others					✓
Performs analyses and experiments related to NDA, holdup measurements, etc.					✓
Plans and coordinates programs and small-scale projects				✓	
Acts as a technical specialist for a nuclear engineering field (nuclear applications in safeguards)					✓
Ability to perform modeling and simulations of detectors and experiments using Monte Carlo Neutral Particle and other tools				✓	
Ability to interact with international experts and IAEA staff				✓	
Ability to train national and international safeguards personnel					✓
Supports independent research and reviews, studies, and analyses in support of technical projects			✓		
Generates creative solutions to work situations					✓
Computer skills				✓	
Maintains high personal standards of performance, responsibility, and professionalism					✓
Ability to write research papers and presentations				✓	
Availability to attend required training and certification	✓				
Ability to communicate with other staff				✓	
Ability to accept criticism				✓	
Ability to face a difficult situation				✓	
Ability to face constant time pressure			✓		
Critical thinking				✓	
Complex problem solving (nuclear safeguards)				✓	
Judgment and decision-making (nuclear safeguards)					✓
Active listening				✓	

3.1.2.2 Safeguards Expert (SME F)

SME F is a nuclear safeguards scientist/engineer and senior R&D staff scientist. He holds two masters degrees in physics and a PhD in nuclear engineering. He has been at ORNL for only 2 years but is a known expert in the safeguards field.

After obtaining his PhD, SME F spent a year as a postdoctoral student at the University of Michigan research reactor, concentrating on the development of a reference neutron field. He then went to work at Canberra as a consultant. Subsequently, he worked full time and stayed at Canberra for 18 years. He started as an entry-level scientist in the physics group and was promoted to senior scientist. His job was science R&D, which is useful to Canberra customers working in health physics, handheld instrumentation, NDA, and radioactive waste disposal. While at Canberra, he worked on new detector materials, gamma spectroscopy, alpha spectroscopy, and semiconductor detectors. He helped develop Canberra's In Situ Object Counting (ISOCS). He also worked on Advanced ISOCS and collaborated with the IAEA for 5 years. The Advanced ISOCS system is now highly useful to IAEA inspectors.

About 30%–40% of SME F's work at Canberra was related to safeguards. The majority of his research involved radiation detection. He modeled the response of a detection system and the conditions under which they could be used in events such as Fukushima.

In his current job at ORNL, SME F writes proposals on new detection technologies (i.e., sensors for neutron or gamma detection) that have an advantage over what is now available. He is also researching a method to aid the IAEA with the swipe samples that inspectors take to HFIR for the purpose of verifying a declared facility's activities and possible identifying undeclared activities. Currently, the samples can only detect very low mass quantities of ^{235}U.

Fellow employees seek SME F's expertise in methods and techniques on neutron and gamma signals, new detectors, uncertainty quantification and propagation, and holdup measurements. He also is involved in Next Generation Safeguards Initiative workshops for university students and training of International Nuclear Safeguards Engagement Program partners. ORNL facilities that play a role in SME F's research include the HFIR and the Safeguards Laboratory. He frequents the ORNL library and refers to the international database of gamma ray spectra.

If he left ORNL, it would take several years for the replacement to come up to speed with the work. It would take about 20 years of experience for someone directly out of college to attain an equivalent level of expertise. For a mid-career person with about 10 years' experience, it would take a minimum of 5 years. Exposure to nuclear safeguards applications experience is necessary.

SME F publishes in *Nuclear Instruments and Methods for Nuclear Research*, *Journal of Radio-analytical and Nuclear Chemistry*, INMM proceedings, European Safeguards Research and Development Association journal, and *Nuclear Science and Engineering*.

He chairs a section on NDA for the INMM and is a member of the American Nuclear Society.

Based on the interview and input from SME F and his immediate supervisor, Table 6 depicts the critical skills for SME F.

Table 6. Critical skills for safeguards—R&D senior nuclear engineer/scientist (SME F)

Critical skills for safeguards SME—R&D senior nuclear engineer/scientist	1	2	3	4	5
Performs independently in a specialty area (radiation detection/measurement technologies) and actively imparts knowledge to others					✓
Ability to apply and develop destructive and NDA measurement methods, automated accounting methods, and containment and surveillance measures for SNM materials and processes					✓
Plans and coordinates programs and large-scale projects		✓			
Deep understanding of what affects measurements, including uncertainty quantification and uncertainty propagation					✓
Ability to perform modeling and simulations of detectors, materials, containers, and experiments using state-of-the-art software				✓	
Ability to interact with international experts and the IAEA staff				✓	
Ability to train national and international safeguards personnel				✓	
Performs independent research and reviews, studies and analyses in support of technical projects					✓
Generates creative solutions to work situations			✓		
Computer skills				✓	
Maintains high personal standards of performance, responsibility and professionalism					✓
Ability to write research papers and presentations				✓	
Availability to attend required training and certification	✓				
Ability to communicate with other staff					✓
Ability to accept criticism				✓	
Ability to face a difficult situation				✓	

Table 6. Critical skills for safeguards—R&D senior nuclear engineer/scientist (SME F) (continued)

Critical skills for safeguards SME—R&D senior nuclear engineer/scientist	1	2	3	4	5
Ability to face constant time pressure			✓		
Critical thinking					✓
Complex problem solving (nuclear safeguards)					✓
Judgment and decision-making (nuclear safeguards)					✓
Active listening				✓	

3.1.2.3 Safeguards Expert (SME G)

SME G is a group leader in international safeguards. He has an undergraduate degree in mechanical engineering and a graduate degree in engineering management. He has been at ORNL for almost 30 years. Before coming to ORNL, he worked at the K-25 Gaseous Diffusion Plant (a former DOE facility for enriched uranium located in Oak Ridge, Tennessee) in operations analysis and planning. He then was involved in international safeguards–related work at the Y-12 National Security Complex (a DOE/NNSA facility in Oak Ridge, Tennessee). He followed the safeguards program when it moved from Y-12 to ORNL.

At ORNL, he works on IAEA safeguards and implementation, with a focus on enrichment activities. Specifically, his skill sets include understanding the operational process, material movement procedures and hardware, material accountability requirements and practices, IAEA objectives for inspections, and measurement technology and capabilities for uranium.

In SME G's group, there is no formal process to capture knowledge. However, there seems to be a growing need now because people do not stay in their jobs as long, and they move on without training others.

ORNL resources that are helpful include RESolutions Publications (which replaced the Publication Tracking System in 2017), a database of documents and presentations. Professional staff members in other divisions at ORNL are also a source of good resources. Training courses are available for management in several areas including communication, problem solving, and interactions. For mid-career employees, the NNSA funds workshops on international treaties and nonproliferation.

In SME G's position, keeping abreast of recent world events related to nonproliferation is a high priority. He keeps current with *Nuclear Engineering International*, watches news programs, and has subscriptions to international journals and news sources. He also attends international nonproliferation conferences and reads papers from the European Safeguards Research and Development Association, the American Nuclear Society, and INMM.

SME G's group has expertise in international safeguards treaties and obligations, nuclear fuel cycle process and activities, and nuclear accounting. As a group leader, SME G tries to hire people who can effectively interact with the sponsors and IAEA Member States, understand material accountability, and understand the nuclear fuel cycle.

In addition to his group leadership position and as an SME in uranium enrichment, SME G serves as a technical resource to NNSA. He has had three assignments at DOE/NNSA headquarters in Washington, DC. He is involved with the universities through NNSA's human capital development program, and he evaluates candidates for the Nuclear Nonproliferation International Safeguards Graduate Fellowship

Program. He is also the ORNL coordinator for the Program of Technical Assistance to IAEA Safeguards, and he provides technical support to the IAEA Department of Safeguards in this capacity.

If he were to leave ORNL, a successor to his group leader position will not require much time to assume the position. It is unsure that they would replace him as an SME because the work evolves, and the future of the position would depend on what the people in the roles are interested in doing. So, the next person would determine what is needed. It would take probably 20 years to become familiar with all the knowledge about the lab and who does what. They would have to have the personality to ask questions because it takes time to build relationships at the lab and in the international safeguards community. Activities and problems are constantly evolving, so SME G's successor needs to be resourceful and have the initiative and self-confidence to do the work. Communication is the most important skill. When a need is identified by the IAEA, this position is responsible for finding experts at ORNL, or other places, and has to fill in the knowledge that the specialists do not have. It has to look at the implementation of the program and it's requirements. It needs to understand the sponsors, the IAEA, and be able to scientifically connect with a person who is technically focused, letting the specialists bring their specialty to the project. It makes connections and monitors the work. Sometimes the expertise is within the group, but the group leader hasto know the skills of others that R&D can access to bring task to fruition.

SME G's group has a SharePoint site, but it is hard to keep it updated with the final versions of documents. A great majority of the information resides on staff's personal computers and is not readily shareable.

SME G is a member of INMM and the World Institute for Nuclear Security. He is the chair of the INMM division on international safeguards.

Based on the interview and input from SME G, Table 7 depicts the critical skills for SME G.

Table 7. Critical skills for safeguards—Safeguards manager (SME G)

Critical skills for safeguards SME—Safeguards manager	1	2	3	4	5
Performs independently in a specialty area (international safeguards) and actively imparts knowledge to others					✓
Knowledge of IAEA safeguards and their implementation				✓	
Knowledge of IAEA safeguards practices on enrichment activities					✓
Plans and coordinates programs and large-scale projects				✓	
Ability to interact with international experts and the IAEA staff				✓	
Understanding IAEA objectives for inspections				✓	
Understanding the operational processes at nuclear facilities				✓	
Understanding material movement procedures and hardware			✓		
Understanding material accountability requirements and practices				✓	
Understanding measurement technology and capabilities for uranium					✓
Availability to attend required training and certification		✓			
Ability to communicate nuclear safeguards with other staff					✓
Ability to accept criticism	✓				
Ability to face a difficult situation					✓
Ability to face constant time pressure			✓		
Critical thinking			✓		
Complex problem solving (nuclear safeguards)				✓	
Judgment and decision-making (nuclear safeguards)					✓
Active listening				✓	
Performs independent reviews, studies, and analyses in of technical projects				✓	

3.2 VALIDATION AND ASSESSMENT OF CRITICAL SKILLS

The interviewers initially prepared tables of critical skill sets based on the responses of interviewees and pre-ranked them (Step 2.1.5). The tables were then sent to the immediate supervisors, interviewees, or both to ensure that no critical skill set was omitted and that each ranking reflected the value of the critical skill.

For the HFIR interviews, we sent the Tables 1–4 to the immediate supervisors. We received feedback from the supervisor of SME A. The rankings in Table 1 reflect the input from the supervisor. We did not receive input for SME B, SME C, and SME D. We noted that SME B and SME C have since retired.

For the safeguards interviews, we sent Tables 5–6 to both the interviewees and prior supervisor in the case of SME E and SME F. Consequently, Tables 5 and 6 reflect input from both the interviewees and prior supervisor. We sought feedback from the previous supervisor because the new manager is not familiar with the nature of SME E and SME F's tasks.

For SME G, we obtained input from the interviewee, who happens to be a group leader. His division had undergone a change in management, and his new supervisor was not familiar with his years of work.

The rankings as drawn up by the interviewers were fairly close to the input from supervisors and interviewees. A handful of critical skills were added by the reviewing supervisor.

3.3 ASSESSMENT OF POTENTIALLY CRITICAL SKILLS

The rankings will be sent back to the managers to aid them in the hiring of potential employees. As of the publication of this document, this step (Step 2.1.6) has not been executed.

4. LESSONS LEARNED

Our approach to testing the methodology was to choose staff from two different organizations: HFIR and the nuclear safeguards groups. The choice of HFIR was dictated by its established structure.

The interview questions were sent to the interviewees at least 2 weeks before the session to allow them sufficient time to prepare. We found this very helpful because most of the interviewees had made notes on the questionnaire, allowing for an efficient session. The interviews lasted from 1–2 hours.

Two of the seven interviews were conducted in an office setting. The others were in conference room settings. The latter setting is preferred to avoid distractions. During the interview, we captured everything the interviewee said so that we had sufficient information to analyze and determine critical skills for that person.

Our initial set of questions, which we used for the HFIR interviews, was lengthy and repetitive. Because of this, we pared it down to the set as listed in Appendix A.

For the HFIR interviews, we sent the ranking tables to the immediate supervisors only. After much thought, we decided to adjust the methodology to include sending the rankings to the interviewees first and then to the supervisors. The latter proved to be a much better approach.

As mentioned previously, a representative from HR adds substantial value to executing the methodology. Also, including one interviewer with technical knowledge related to the interviewees' skills sets is desirable.

5. CONCLUSIONS

The identification of critical skills plays an important role in succession planning. A methodology to identify such skills was presented in a previous report by the authors (Ron Cain, Shaheen Dewji, Carla Agreda, Bernadette Kirk, July 2017). The authors took the proposed draft methodology and tested it in this report to demonstrate its utility. To test the methodology, interviews of seven technical experts were conducted. Each interview led to a critical skill set analysis based on the questions asked. The table of critical skills for each SME was developed by the interviewers from the answers to the interview questions. Out of the seven interviews, the table was modified and verified in four cases by either the immediate supervisors, the interviewee, or both. The methodology is subject to changes and can be refined further by respective institutions that may want to adopt it. Similarly, the interview questions can be modified.

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APPENDIX A. TECHNICAL EXPERT INTERVIEW QUESTIONS

These questions are derived from the IAEA (2006) and Lucas (2017) and adapted for the purposes of our study.

TACIT KNOWLEDGE

1. What is your job title?
2. What educational background do you have?
3. How long have you been with the organization?
4. Do you have experience as an expert in previous jobs that relates to your current job?
5. What is your major function in your current job?
6. For your current role, what unique skill sets are required? In what areas do fellow employees seek your expertise?
7. Does your workplace have a process to capture vital knowledge?
8. What available organizational resources aid you in performing your job?
9. Does your work necessitate that you to keep up with publications (e.g., open literature)?
10. Other than the general organizational requirements, do you have to attend job-specific critical training on a regular basis? How often?
11. What other roles do you have?
12. If you had to leave the organization for any circumstance, how long do you think it would take for someone to adequately assume your role?
13. In relation to the above question, what would be the timeframe for training your replacement?

EXPLICIT KNOWLEDGE

1. Does a physical library exist for documented resources?
2. Are there databases available?

PROFESSIONAL ACTIVITIES

Are you a member of a professional society? If so, how does the membership add value to your job?