Integration of Human and Organizational Factors in Canada: Enhancing Nuclear Safety

M.K. Heppell-Masys CD, MEng [1], S. Dolecki, BA/BPHE, Bed [1]

[1] Canadian Nuclear Safety Commission

Kathleen.heppell-masys@cnsc-ccsn.gc.ca

Abstract The integration of Human and Organizational Factors (HOF) within a regulatory framework will strengthen the actions of a Technical Support Organization (TSO), lead to a more effective regulatory oversight and result in improved nuclear safety regulatory system. The importance of HOF has long been recognized as critical to safe operations. As safety results from the interaction of individuals with technology within the organisation, as indicated in the IAEA in Safety Standard GS-G-3.5, "The Management System for Nuclear Installations", a sound safety oversight should encompass this interaction as well. This paper will describe how the Canadian Nuclear Safety Commission (CNSC) has developed a robust regulatory framework which supports our oversight in the area of HOF. CNSC's Safety and Control Area framework explicitly identifies the integration of HOF within its regulatory oversight activities. While there is still work to be done, practical examples are provided which demonstrate how the CNSC has achieved successful integration amongst technical disciplines and the benefits realized from this approach. One of the most significant benefits is in the synergy created when specialists from various disciplines interact, share knowledge and approach safety from a holistic perspective. This integrated approach ensures the continuous development and availability of the scientific expertise necessary to support an effective nuclear safety regulatory system.

1. Introduction

Large scale accidents such as Three Mile Island (1979), Chernobyl (1986), Challenger (1986), Columbia (2003), Texas City refinery explosion (2005), Deep Water Horizon fire and explosion at the Macondo Well (2010) rarely happen due to a single technical failure. Investigations reveal a complex set of interactions of many seemingly unrelated factors which combine to create the conditions in which an organization is vulnerable. The contribution of the interactions between the human, technological and organizational factors contributed to each of these significant events and has been identified in analysis of the Fukushima Daiichi accident [1].

It is a challenge to design an effective regulatory oversight system which considers each of the individual, technical and organizational factors which can affect performance. The interactions between all of these factors must be anticipated when considering if an individual can complete the required actions safely and successfully. This requires the integration of the full range of human and organizational factors present across all activities within the management system of the licensee. This approach moves the focus from errors committed by front line workers to an emphasis on examining the deeper cultural and organizational issues which influence human performance and have been identified as precursors to catastrophic events [2].

This paper will describe how the CNSC has structured its regulatory oversight approach and supporting regulatory tools, to address the human, organizational and technical factors which affect nuclear safety.

2. Human and Organizational Factors

The Directorate of Safety Management (DSM), in the Technical Support Branch of the CNSC, supports the regulatory mission and mandate of the CNSC by providing leadership and expertise in the areas of Human and Organizational Factors, Management Systems, Training Programs and Personnel Certification. Staff from DSM contribute to planning, implementing and evaluating safety management programs across the range of nuclear facilities and activities regulated by the CNSC.

Nuclear power plant licensees in Canada have a requirement to establish a management system (MS) in accordance with Canadian Standards Association (CSA) N286 which integrates the provisions for the management of health, environment, security, quality and economics [3,4]. An effective management system integrates all elements of management so the requirements for safety are established coherently with other requirements [4]. An effective management places the highest priority on safety in all decisions and actions and is the cornerstone of a healthy safety culture.

The requirement to implement a management system ensures that licensees integrate the programs at each facility and establish safety as the paramount priority in decision making and activities.

The IAEA (2014) [1] supports a systemic approach to safety addressing:

'…the whole system by considering the dynamic interactions within and among all relevant factors of the system — individual factors (e.g. knowledge, thoughts, decisions, actions), technical factors (e.g. technology, tools, equipment), and organizational factors (e.g. management system, organizational structure, governance, resources)'

For the purpose of this paper, human and organizational factors can be conceptualized as the foundation supporting human performance, as shown in Figure 1. Effective human performance integrates the full range of human factors considerations across all organizational functions and activities.

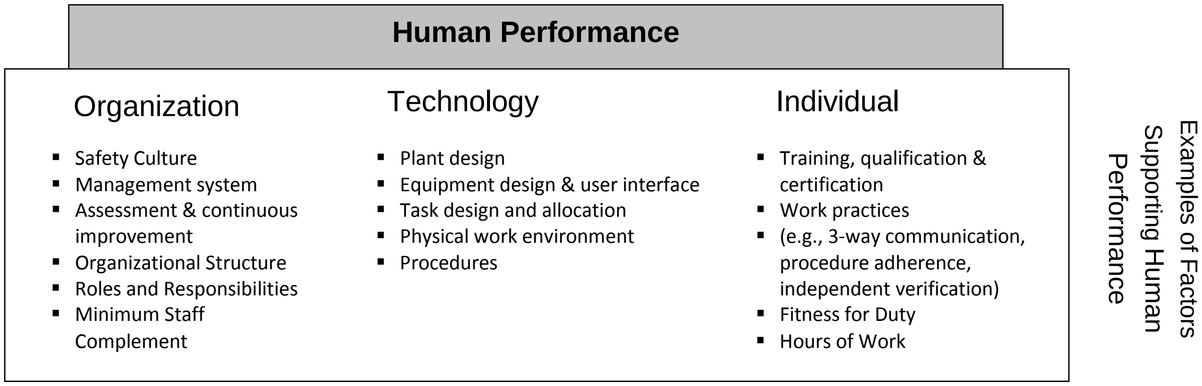

Figure 1: Human and organizational factors related to the organization, technology, and individual can be conceptualized as the foundation that supports human performance. Examples of human and organizational factors are shown in this figure. Changes to the factors that affect human performance will influence how workers perform their job duties affecting overall nuclear safety

3. CNSC Regulatory Framework

The CNSC has established a well-defined regulatory framework that consists of laws passed by Parliament, regulations, licences and regulatory documents, as shown in Figure 2. The Nuclear Safety and Control Act empowers the Commission to make regulations and to develop other regulatory tools to establish requirements and provide guidance related to the use of nuclear energy in Canada [5]. Regulations set out statutory requirements. Licences include conditions to which licensees must adhere. The CNSC's regulatory documents provide greater detail as to what an applicant or licensee must achieve to meet the CNSC's regulatory requirements.

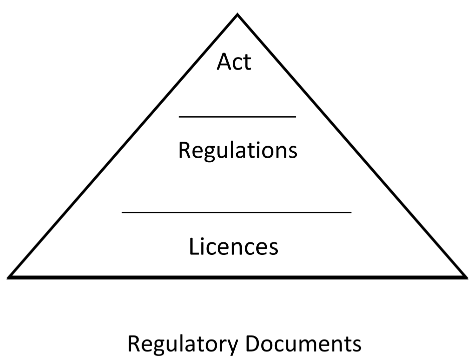

Figure 2: Overview of regulatory framework.

Human and organizational factors are addressed throughout the regulatory framework. The Nuclear Safety and Control Act [5] and Regulations include a number of requirements that enable the CNSC to address human and organizational factors. For example, the Nuclear Safety and Control Act requires licence applicants to be qualified and to make adequate provision for the protection of the environment, the health and safety of persons, and the maintenance of national security (Section 24(4) of Reference 5). The General Nuclear Safety and Control

Regulations include a range of requirements that address human and organizational factors applicable to applicants, licensees and workers (e.g., Sections 3, 12 and 17 of Reference 6).

Licences include conditions supporting human and organizational factors. For example, nuclear power plant licences require licensees to implement and maintain the following:

- A management system in accordance with CSA N286 standard [3]
- A human performance program;
- A minimum staff complement in the facility at all times;
- A training program; and
- A certification training and examination program.

The CNSC has a number of regulatory documents that focus on human factors [7-10] and others that embed human factors requirements such as design, maintenance, accident management and emergency response [11-15]. Forthcoming regulatory documents will address safety culture, human performance, fitness for duty and fatigue. A full set of regulatory documents is available on the CNSC's website at www.nuclearsafety.gc.ca.

4. CNSC Safety and Control Area Framework

The Safety and Control Area (SCA) Framework was created by the CNSC to provide structure to the oversight and regulatory activities applied to all licensed activities and facilities that the CNSC regulates. The SCA framework consists of 14 safety and control areas which are grouped into three primary "functional" areas (Management, Facility and Equipment, and Core Control Processes). This structure also serves as the guiding framework for the development of regulatory documents in support of licensing and compliance decisions. This is a systematic approach towards ensuring that the elements necessary for nuclear safety are addressed in a consistent manner.

HOF topics are specifically identified and integrated within 5 of the 15 SCAs in the framework (Table 1). There is a further breakdown of the SCAs into Specific Areas. At this level different divisions across the CNSC are identified as having either a lead or contributing role. The formal identification of HOF as either a lead or contributor is printed in italics in the table below. In the remaining areas, integration and collaboration occur on an informal basis.

Table 1: SCA Framework

Functional Area	Safety and Control Area	HOF Related - Specific Areas
Management	Management System	Management System Organization Performance Assessment and Management Review Operating Experience Change Management Safety Culture Configuration Management Records Management Management of Contractors
	Human Performance Management	Human Performance Program Personnel Training Personnel Certification Initial Certification Examinations and Requalification Tests Minimum Staff Complement Fitness for Duty
	Operating Performance	Procedures Reporting and Trending Accident Management and Recovery
Facility and Equipment	Safety Analysis	Human Actions in Safety Analysis Human Reliability Analysis
	Physical Design	Human Factors in Design
	Fitness for Service	
Core Control Processes	Radiation Protection	
	Conventional Health and Safety	
	Environmental Protection	
	Emergency Management and Fire Protection	
	Waste Management	
	Security	
	Safeguards and Non-Proliferation	
	Packaging and Transport	

The inclusion of HOF within the SCA framework is the primary method by which the regulatory oversight of human and organizational factors is integrated across the CNSC.

5. Practical Examples and Benefits

Minimum Staff Complement:

Work done by the CNSC to assess the Minimum Staff Complement (MSC) of a licensee demonstrates the application of a multi-disciplinary and integrated approach to regulatory oversight.

The General Nuclear Safety and Control Regulations section 12 (1) (a) [6] requires licensees to, "ensure the presence of a sufficient number of qualified workers to carry on the licensed activity safely." Licensees meet this requirement by defining MSC which is the "minimum number of qualified workers who must be present at all times to ensure the safe operation of the nuclear facility and to ensure adequate emergency response capability." CNSC regulatory document G-323, entitled, Ensuring the Presence of Sufficient Qualified Staff at Class I Nuclear Facilities – Minimum Staff Complement [9], outlines the CNSC's expectations for conducting the baseline analysis and validation, monitoring for compliance and controlling changes to the MSC. MSC includes certified staff but also includes workers from all work groups required to conduct the licensed activity safely and to carry out emergency response actions. MSC does not refer to the overall staffing levels at a station. Figure 3 displays a graphical representation of MSC.

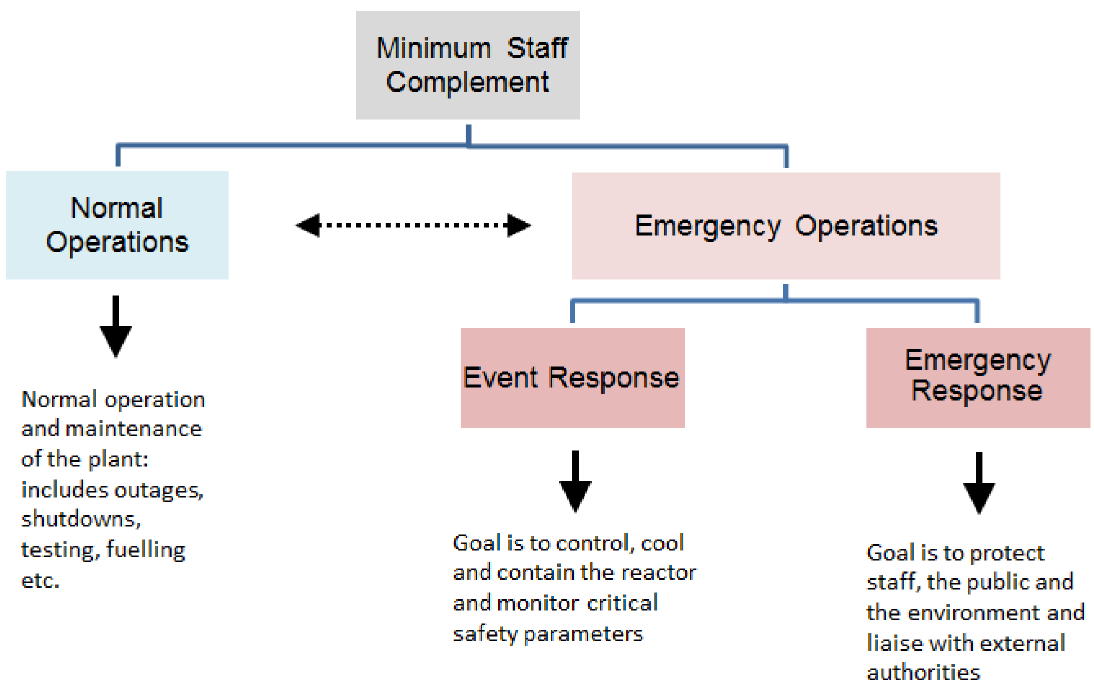

Figure 3: Minimum Staff Complement Framework

During this project, the licensee first conducted a systematic analysis to identify the most resource-intensive conditions under all operating states, design basis accidents and emergencies. The documentation reviewed included the following: events identified in the safety report, probabilistic safety analysis, credited operator actions, emergency operating procedures and operating strategies. From this initial analysis, the number and qualifications of staff required for the MSC was proposed. Following the analysis phase, validation exercises were conducted to demonstrate the adequacy of the MSC in achieving the safety goals. In this case, the safety goals are to control, cool and contain the reactor.

A multi-disciplinary approach was used by both the licensee and the CNSC in order to ensure a thorough understanding of event progression and staffing requirements for the resource-limiting event. The figure 4 below identifies the range of specialist expertise involved in this project at the CNSC.

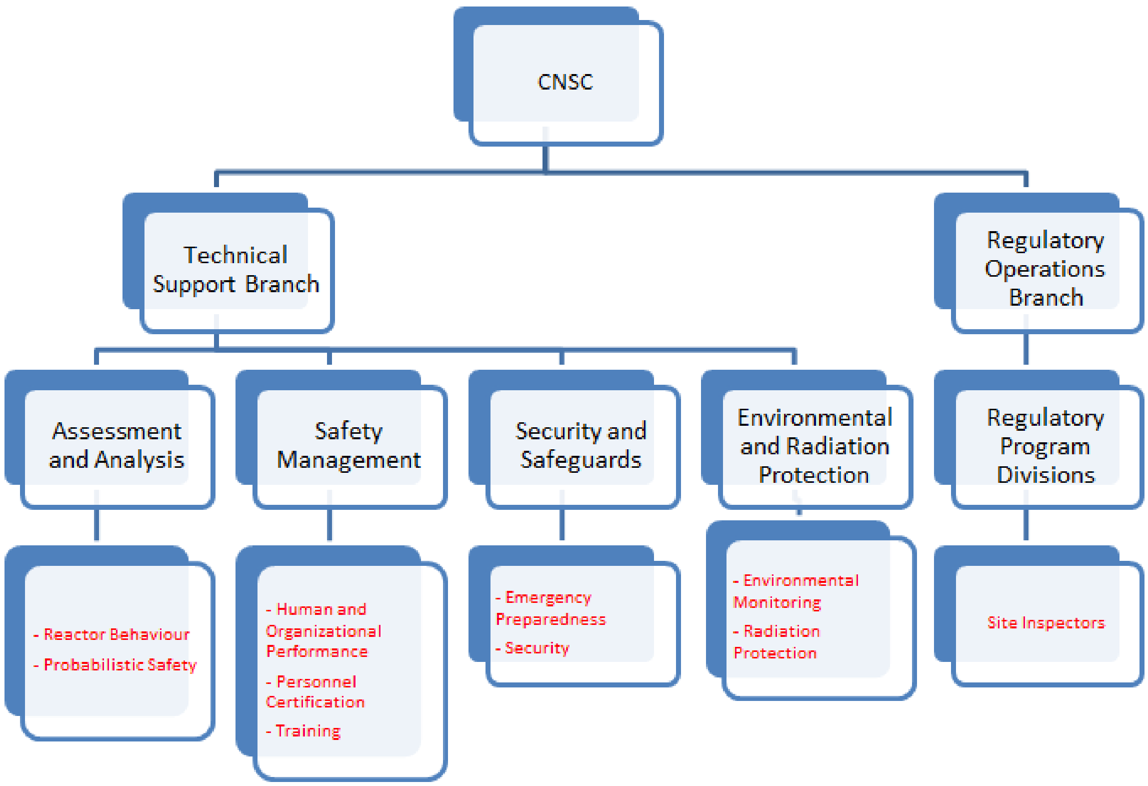

Figure 4: CNSC Participating Divisions

CNSC staff working on this project identified the following benefits:

- Holistic understanding of event progression including activities for event and emergency response in the main control room, secondary control rooms and the field
- Development of a cross-disciplinary knowledge base amongst specialists on the team
- Sharing of knowledge between specialists from different disciplines and with varying levels of expertise (knowledge management)
- Improved working relationships with specialists from multiple divisions in the technical and operations branches across the CNSC
- Breaking down of silos between different organizational units

From the licensee perspective, the multi-disciplinary approach identified the following opportunities for improvement:

- Coordinated training for main control room and field operations staff in the simulators and in the field.
- Improvements to command and control practices when the main control room is uninhabitable
- Training on the functionality and use of emergency communication systems
- Improved availability of personnel protective equipment
- Procedure and equipment configuration issues addressed
- Improved assembly and accounting procedures to maximize response

This project serves as an excellent example of how an integrated and multi-disciplinary approach to regulatory oversight can lead to improvements in nuclear safety. As the HOF specialist was the lead on this project, the interaction of the human, organizational and technical factors was a paramount consideration.

Other Examples:

In response to the Fukushima event, the CNSC developed an Action Plan to identify areas for improvement amongst NPP licensees. HOF were integrated in the closure criteria for many of the action items. HOF staff continue to be actively involved in monitoring and assessing licensee completion of the Fukushima station specific action items.

HOF requirements are explicit in a broader range of CNSC regulatory documents. Writing teams are comprised of individuals from a variety of disciplines which leads to a more holistic treatment of the topic under discussion. For example, HOF specialists were invited to participate on the writing teams of two recent regulatory documents: Accident Management and Nuclear Emergency Preparedness and Response [14-15].

Compliance verification activities are carried out by specialists from multiple divisions in the Technical Support Branch and inspectors from the Regulatory Operations Branch. The CNSC is moving towards the development of integrated inspection guides that support the work of participants from multiple disciplines.

For smaller licensees such as processing facilities and research reactors, multi-disciplinary teams that include HOF specialists manage facility oversight based on a graded approach to risk.

6. Conclusion

The treatment of HOF at the CNSC is formalized in the SCA framework and supported by a robust suite of regulatory documents. The formal integration ensures that the human and organizational factors which have been shown to have an impact on nuclear safety are addressed in a systematic and consistent manner. This integrated approach has resulted in benefits realized by both the licensee and the CNSC. The licensee has identified and implemented tangible changes which have improved nuclear safety. For the CNSC, an integrated and collaborative approach has enhanced the development and availability of technical expertise which strengthens the actions of the Technical Support Branch. This supports an effective nuclear safety regulatory system which leads to improved nuclear safety in the Canadian industry.

Appendix 1:

1. International Atomic Energy Agency Report on Human and Organizational Factors in Light of the Accident at the Fukushima Daiichi Nuclear Power Plant. International Experts Meeting, 21-24 May 2013, Vienna, Austria http://www.iaea.org/newscenter/focus/actionplan/
2. Taylor, R. H. et al., "A Study of the precursors leading to 'organisational' accidents in complex industrial settings." Process Safety and Environmental Protection 2014) http://dx.doi.org/10.1016/j.psep.2014.06.010
3. CANADIAN STANDARDS ASSOCIATION (2012), Management System Requirements for Nuclear Facilities, CSA N286-12.
4. INTERNATIONAL ATOMIC ENERGY AGENCY (2006), Management Systems for Facilities and Activities, GS-R-3, http://www-pub.iaea.org/MTCD/publications/PDF/Pub1252_web.pdf.
5. Nuclear Safety and Control Act, Last amended on June 29, 2012 (1997, c. 9),

   http://laws-lois.justice.gc.ca/eng/acts/N-28.3/index.html.
6. General Nuclear Safety and Control Regulations, last amended on April 17, 2008 (SOR/2000-202), http://laws-lois.justice.gc.ca/eng/regulations/SOR-2000-202/index.html.
7. CNSC (2003), Human Factors Engineering Program Plans, G-276, http://www.nuclearsafety.gc.ca/pubs_catalogue/uploads/44019-G276E.pdf.
8. CNSC (2003), Human Factors Verification and Validation Plans, G-278, http://www.nuclearsafety.gc.ca/pubs_catalogue/uploads/G278_e.pdf.
9. CNSC (2007), Ensuring the presence of sufficient qualified staff at Class I nuclear facilities – minimum staff complement, G-323, http://www.nuclearsafety.gc.ca/pubs_catalogue/uploads/G-323_e.pdf.
10. CNSC Regulatory Document, "Human Performance Management: Personnel Training REGDOC 2.2.2" http://www.nuclearsafety.gc.ca/eng/acts-and-regulations/regulatory-documents/history/regdoc2-2-2.cfm
11. CNSC (2008), Design of new nuclear power plants, RD-337, http://www.nuclearsafety.gc.ca/pubs_catalogue/uploads/RD-337_e.pdf.
12. CNSC (2011), Licence Application Guide – Licence to construct a nuclear power plant, RD/GD-369, http://www.nuclearsafety.gc.ca/pubs_catalogue/uploads/August-2011-RDGD-369-Licence-Application-Guide-Licence-to-Construct-a-Nuclear-Power-Plant_e.pdf.
13. CNSC (2012), Maintenance Programs for Nuclear Power Plants, RD/GD-210, http://www.nuclearsafety.gc.ca/pubs_catalogue/uploads/20121212-RDGD-210-maintenance-programs-nuclear-power-plants-eng.pdf.
14. CNSC Regulatory Document, "Operating Performance: Accident Management, REGDOC 2.3.2."
15. CNSC Regulatory Document, "Emergency Management and Fire Protection: Nuclear Emergency Preparedness and Response, REGDOC 2.10.1."