A PHASED APPROACH TO HUMAN FACTORS INTEGRATION – POINT LEPREAU EME DEPLOYMENT CASE STUDY

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Abstract

Following CNSC Regulatory Policy *P-119 - Policy on Human Factors*, all Canadian utilities licensed by the Canadian Nuclear Safety Commission (CNSC) are required to consider human factors in all phases including design, construction, commissioning, operation, maintenance and decommissioning. In conducting human factors assessments of design modifications, utilities generally consider human factors during the design phase as part of the engineering change control process. However, performance of human factors assessments before and/or after the design phase can be more effective and reduce unnecessary engineering effort. A recent human factors assessment performed at the Point Lepreau Nuclear Generating Station demonstrates some of the synergies that can be achieved by using a phased approach to human factors assessments. This case study is presented as evidence that a phased approach to human factors integration has merit and should be considered in the future by the industry.

1. Introduction

Engineering Change Control (ECC) processes generally screen for human factors during modification scoping at the outset of the design phase (note that special projects conducted to fulfill identified analysis needs may follow a different process). However, the human factors assessment itself is generally not started until sometime during preliminary or detailed design and is largely completed by the end of detailed design. This sometimes results in significant effort on the part of specialists to pre-empt future issues and rationalize design decisions made previously. This de facto limitation of the review to the design phase presents a motivation to identify and immediately resolve all human factors issues. However, this is not a realistic expectation.

Invariably, there will be emergent issues later that could not be foreseen. For example, detailed vendor documentation is often not available for review during the design phase. Consequently, issues with procured equipment may not be discovered until installation and commissioning. In other cases, validation exercises using low fidelity mock-ups, untrained personnel and incomplete procedures are insufficient to root out key issues. Similarly, human factors specialists often inherit the responsibility to rationalize design decisions related to alternative selection and specification of design requirements. This is particularly evident during functional requirements analysis and function allocation.

The apparent solution to the above is to conduct human factors assessments when the necessary information is available. This means both a) delaying some human factors review until it can be completed thoroughly, and b) conducting early human factors reviews while the cost of design changes is small. It is important to recognize that this paper does not present an argument to increase

the level of human factors effort overall, but rather to apply expertise when it will have the most positive impact. Note that specific process modifications are beyond the scope of this paper.

2. Point Lepreau Emergency Mitigating Equipment (EME) Deployment

In response to the CNSC Integrated Fukushima Action Plan, New Brunswick (NB) Power's Point Lepreau Nuclear Generating Station implemented a series of design modifications to enhance the plant's ability to address beyond design basis accidents through procurement of mobile Emergency Mitigating Equipment (EME) and installation of connection points. As part of NB Power's design process and in preparation for the provincial emergency response exercise Intrepid 2015, a human factors assessment was conducted at the Point Lepreau Nuclear Generating Station to validate the EME deployment strategy. The assessment integrated information from various engineering design packages, previous human factors assessments and direct input from station stakeholders including Operations, Nuclear Response Force (Security) and Emergency Response Team (Fire).

Given that the various design modifications were targeted to address specific system modifications (e.g. water and electrical tie-ins to critical plant systems), the previous human factors evaluation of each modification was necessarily limited to the individual scope. As a result, it was recognized that an integrated human factors review of the deployment strategy was needed in order to complete human factors activities and meet NB Power's design process. Given the nature of the special project, this assessment was conducted using the purchased EME, in parallel with personnel training, installation and commissioning. There were several key advantages to this approach:

1. Field verification
2. Highly specific operating experience
3. Low cost / high fidelity validation

The following sections discuss these advantages of a phased approach to a human factors assessment.

2.1 Advantage 1: Field Verification

Field verification is notably more straightforward than performing human factors design verification and task support verification using engineering drawings which often lack pertinent details. This is particularly applicable to purchased equipment where vendor documentation is not received during the design phase. Instead, the installed systems, structures and components and mobile equipment were inspected directly in the context of the surrounding plant area(s). It was readily confirmed that the human system interfaces were accessible, conformed to Human-System Interface (HSI) requirements and supported the pertinent tasks. Additionally, this method of inspection allowed identification of contextual human factors. One example of the latter occurred during inspection of the deployed spent fuel bay make-up line.

During a beyond design basis accident, the spent fuel bay inventory may be restored using a deployed hose and portable fire monitor (deluge gun). One of the designated deployment locations contains switchgear which could potentially be wetted by the water spray. This observation was recorded and addressed accordingly.

This issue would have been difficult to predict based on design products alone as the design only specified the hoses and monitor. At a minimum, the observation would have required a verification walkdown after the deployment location had been established. For a typical modification, deployment is usually not required and, therefore, not considered. In this case, the spent fuel bay makeup involved no modification to structures, systems and components but was subjected to the same scrutiny as a modification.

2.2 Advantage 2: Highly Specific Operating Experience

The phased approach to the human factors assessment afforded the opportunity to record highly specific Operational Experience (OPEX) discovered during training exercises and during installation and commissioning. Much of this OPEX was related to simple operational difficulties and solutions such as fraying of cable storage straps, equipment to prevent the EME trailer jacks sinking into the mud during wet conditions and daisy chaining cables to reach potentially obstructed connection points.

In addition to simple issues, other operational challenges were highlighted by station staff. One notable example was the establishment of a standard radio communication protocol between interacting operational groups, which improved coordination of the EME deployment. This represented an important step in validating the EME deployment as communication between groups during deployment is critical to success.

This OPEX was shared amongst stakeholders and recorded in the human factors assessment as evidence of human factors consideration during implementation of the EME modifications. Though this OPEX would likely have been documented elsewhere, perhaps at a later stage in training, it is important to take credit for the consideration of human factors where applicable.

2.3 Advantage 3: Low Cost / High Fidelity Validation

The post-installation validation experienced synergies with the station training department, which was conducting training exercises and evaluations in parallel. Under typical circumstances, one of the challenges to performing a human factors validation during the design phase is that the validation participants generally have minimal training in the specifics of the modification since training takes place after design completion. In this case, participants were well-trained and familiar with the equipment and tasks by the time the HF validation was conducted.

Additionally, the training exercises themselves were an excellent opportunity to conduct the validation. The training exercises brought together the interacting end users and employed actual equipment in scenario-based tasks representative of the final use-cases. As such, they fulfilled many of the key requirements of a human factors validation with minimal additional effort – essentially one specialist to observe, interview participants and administer questionnaires. In constrast, validations conducted during design are often performed as tabletop exercises by necessity as the systems, structures and components are not typically installed/constructed.

The additional fidelity was important for identifying certain issues which likely could not have been discovered during a design validation. For example, it was discovered that the suction hose on the EME water pump presented problems maintaining a vacuum due to air ingress at the seals between segments of the hose. This issue was resolved by procedural changes and training.

3. Challenges

Although a phased approach to human factors integration has benefits as illustrated above, there are challenges to be addressed:

1. A phased approach means that human factors involvement in the project would necessarily be prolonged, which in turn means that the human factors analysis may be performed by different personnel over the course of the project. It is therefore necessary for the human factors analysis records to stand alone such that the content can be built upon during subsequent assessments. Well-written reports and rigorous action tracking are key components of this approach;

2. Organizational processes and screening methods would need to be adapted to ensure that the human factors reviews are invoked during the intended phases, and the corresponding records retained. As discussed previously, this paper does not attempt to prescribe an allocation of human factors review elements to specific project phases. However, it is worthwhile to note that some flexibility in the timing of human factors assessments is likely necessary to meet the differing demands of projects, but should be applied at the discretion of well-trained personnel and fit within an integrated assessment strategy, and;

3. The existing challenge of costly late identification of issues could potentially be exacerbated if a phased approach is implemented incorrectly.

4. Additional Perspectives

Though this paper has largely focused on the application of late-stage human factors review as a phased approach, it is expected that early consideration of human factors would also yield benefits. It is clear from NUREG-0711 Human Factors Engineering Program Review Model that earlier elements of the review model such as OPEX review, functional requirements analysis and function allocation are intended as inputs to design requirements and would ideally take place during pre-design planning. The avoided cost of rework afforded by upfront requirements could be significant.

It is also worthwhile to note that not all activities required for a human factors review necessarily need to be performed by a human factors specialist. Portions of the work could be done more efficiently by a design engineer or training coordinator (supported by operations, maintenance and other stakeholders as applicable) and subsequently reviewed by a human factors specialist, where deemed appropriate. While human factors is considered a specialist domain, in reality a large share of the value created by human factors is simply the integration of information from multiple sources (design engineering, operations, maintenance, vendors, etc.). This is particularly true of large, multidisciplinary but ultimately straightforward modifications. However, certain aspects of human factors assessments, such as detailed timeline analysis, cognitive work analysis, significant HSI design, and human reliability analysis generally require specialist expertise.

The task of integrating the pertinent information over the course of a multi-phase project is significant. Given that so much human factors work in the nuclear industry is performed in support of large multidisciplinary engineering projects, the opportunities for cost savings are also potentially significant. In addition to the potential for cost savings, the positive impact on quality is a major consideration. As discussed in this paper, many stakeholders contribute to ensuring that human factors are considered in the design and implementation of station modifications, but credit is not necessarily taken for it as such. The documentation of human factors assessment in a cohesive, auditable format is a critical component of a quality design program.

5. Conclusion

The Point Lepreau Nuclear Generating Station EME deployment human factors assessment demonstrated that a phased approach to human factors can provide cost savings and improve effectiveness of assessments by realizing synergies with other stakeholders. This case study is presented as evidence that a phased approach to human factors integration has merit and should be considered by the Canadian nuclear industry.