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EDITORIAL

Human factors in nuclear safety: present and future

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1 Introduction to the special issue

Investigations have shown that inadequate human control has caused or worsened numerous incidents across the high-hazard industries, including Piper Alpha, Bhopal, Browns Ferry Nuclear Power Plant, Chernobyl and the BP Texas Refinery. These incidents have had terrible safety consequences, but they have also provided insight into why they have occurred. There is now a greater awareness of the determinants of safety in large complex systems as well as a growing awareness of the part that human factors (HF[1]) play in accidents, either as part of the event sequence or as part of the mitigation and recovery. It follows that there is now a suite of established methods available for applying HF in the nuclear industry, which serve to shape human performance in complex high-hazard systems in order to serve reliability and safety. This special issue provides a cross-section of such applied HF from within the UK nuclear industry, covering the lifecycle of a nuclear plant including design and commissioning, operational life and decommissioning.

Consistent with the focus of *Cognition, Technology and Work*, the aim of this special issue is to show how the HF discipline deals with the interactions between people and their technology at different levels of the organisation, centred on the system. It places emphasis on the need to address the whole work system and organisation rather than any isolated unit of human task/s, although the latter is, of course, included in the scope of the former. This special issue therefore touches upon the range of methods employed and the progress made in certain keys areas of HF. It is timely to dedicate a special issue of CTW on HF in nuclear safety since the industry in the UK is entering a renaissance with new nuclear build. Furthermore, the Fukushima incident has highlighted the need to continually review and scrutinise the methods and approaches used to achieve safety in the nuclear domain.

This editorial frames the special issue within the context of the variation, stress and change that nuclear organisations might contain and experience during their life in order to consider where the HF discipline fits in achieving and also maintaining organisational safety.

2 System variation, stress and change

Arguably, if all plant systems in the nuclear industry were the same and operated under the same conditions and environment throughout their life, the HF application may be straightforward and the need for research is limited. This of course is not, and never will be, the case. There will always be variation in people and in the operations that they control. Organisations will always be predisposed to change and stress in different forms. They may experience sudden management

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[1] Throughout this Special Issue, we use the terms HF and Ergonomics interchangeably. Any debate concerning differences between them tends to be solely etymological.

takeovers and organisational restructuring. With finite plant life, there is an inevitable transition in decommissioning. With new technology, there is always the pressure for systems to evolve. Operating in wider environments, an organisation may experience sudden stress, with a state of emergency that demands an immediate concerted human response. The wider social and economical environment may instead impose a slow change on an organisation, so that the effects on safety may not be realised for some time. In all cases, there is a need to address the human factors involved with proportionate analysis in order to ensure that the organisation achieves and maintains safety, regardless.

There exists a range of HF issues associated with current plant (often referred to as 'Generation II') and proposed designs currently under review ('Generation III+'). These will include, but not be limited to, the socio-technical impacts of emerging technology, validity of current safety assessment methods, including human reliability assessment methods, plant life extension, and maintenance of ageing plant and emergency response management. Three overarching issues emerge from this, arising from the longevity of nuclear power plant operations.

(1) Emerging technology will start to offer solutions not previously considered and novel HF challenges.
(2) There is the potential for the organisation to gradually and imperceptibly to drift away from the standards it believes it is achieving and to fail to keep up with developing standards throughout its lifecycle.
(3) Human error in management, supervision and maintenance becomes increasingly important in long-lived organisations, and hence, the manner in which organisational design controls this vulnerability increases in importance.

Thus, many different issues may influence nuclear organisations by imposing a range of variation, stress and change on its operations; some are sudden and obvious, while others are more subtle and difficult to detect and measure. The various factors described can collectively affect the performance of people, systems and safety. However, some of the human and organisational factors implicated are the least understood in safety management and the most difficult to defend against through engineering and account for in safety assurance. A deep understanding of HF involved in risk management is required if effective support to industry is to be provided.

3 Where does HF fit?

Fortunately, the HF discipline has a breadth and depth of coverage and a range of scientific and practical methods, so that we can address many of the factors influencing organisational safety, from the micro- to the macro-level of an organisation. The HF discipline encompasses a wide subject-field, ranging from physical, cognitive and systems ergonomics to individual, group and organisational psychology. It can therefore address the design of peoples' work, their workstations, the systems of which they are a part, and the whole organisation in which people operate. By integrating knowledge from a wide spectrum of disciplines, and through research, HF can also enhance individual, team and system performance. It can potentially help in the scrutiny of the way in which organisations behave as a whole. This SI provides a sample of the range of HF applied in the UK nuclear industry, and the potential research associated with it, as follows:

4 Special issue content

1. Practical human factors integration in the nuclear industry by *Ian Hamilton* et al., *Lloyds Register Human Engineering, UK.*
2. Defining and assessing safety functions performed by people by *Andy Bardsley*, *Atomic Weapons Establishment, UK.*
3. Applying human reliability assessment methods to human–computer interfaces by *Ned Hickling and Jane Bowie*, *Office for Nuclear Regulation, UK.*
4. A human performance programme to improve front-line nuclear operations by *Sarah Peck National Nuclear Laboratory, UK.*
5. Developing an organisational integrity framework for nuclear safety by *Gary Moon and Ian Hamilton, Lloyds Register Human Engineering, UK.*
6. The human factors of project team decision-making for radioactive waste management by *David Collier*, *Golder Associates, UK.*
7. Widening the scope of HF safety assessment for decommissioning by *Ceri Owen* et al., *Atomic Weapons Establishment, UK.*
8. Developing guidance on the safe use of air-fed suits in the nuclear industry by *Claire Millard* et al., *Health & Safety Laboratory, UK.*

5 Summary points

This special issue shows that the HF discipline is an integral part of nuclear safety engineering and offers considerable potential for enhancing organisational safety.

5.1 Some strengths of applied HF in the nuclear domain

(1) Established HF methods fit logically in a structured engineering process for design, along a hierarchy of

hazard treatment—from elimination, reduction, isolation, control, protection and discipline (ERICPD).

(2) Human error probabilities and engineered component failure probabilities share fault models and design objectives, thus integrating human and engineering in the same design scheme.
(3) Hazards and their consequences can direct the resources of the HF work, proportional to the risk associated with the given design.
(4) In dealing with interactions and interfaces involved in the design of complex systems, HF helps bridge the various disciplines involved and achieve a systems approach in order to meet the shared objectives in design and in safety management.

However, if the benefits of HF are to be realised, the discipline must address various weaknesses in its application.

5.2 Some weaknesses of current applied HF in the nuclear domain

(1) Engineering designers may too readily rely upon human discipline along the ERICPD risk reduction strategy, thus shifting the locus of potential error to areas such as management, supervision and maintenance.
(2) There is the misperception in some quarters that the discipline only deals with human error and that any consequence of its practice is to change human behaviour not system design; HF assessment and utility can be narrow in its scope.
(3) HF practitioners tend less often to be involved in aspects of organisational change, learning and development, compared with other domains (i.e. the military, rail), where HF is integral.
(4) The lack of a shared, defined view on the purpose, scope and utility of HF within the industry may cause inconsistency and even impairment in its application.

6 Discussion

HF features heavily in the formal assessment of nuclear safety, particularly in design (i.e. Hamilton et al.), and aligns well with engineering, but not without some practical challenges (Bardsley). There is still a need to carry out research and to scrutinise the validity of the data on which human reliability assessment for new tasks might depend (Hickling and Bowie). We should endeavour to reduce the reliance on the human performance for safety where possible and not rely too readily on human discipline to resolve design inadequacy caused by a lack of HF integration and awareness from the outset. A greater understanding of the human factors of the management decision-making involved in engineering design teams themselves will assist in this endeavour and serve to reduce latent errors in future systems (Collier). Furthermore, a widening of the scope of HF assessment in the design stage of a system may make later transitions or adaptations safer (Owen et al.), and a systems approach to hazardous work in protective equipment will have clear benefits to personal safety and system reliability (Millard et al.). There seems to be a need for more effective integration of the HF discipline into engineering projects and organisational management, in general.

It would be useful for the nuclear industry to develop its application of HF, so that there is some consensus about where it fits across the various functions of a nuclear licensed site throughout its life for the purpose of nuclear safety. We have established models of HF centred on the person embedded in systems for achieving high levels of human reliability in design (Bardsley). However, we lack an established framework of HF application centred on the organisation for dealing strategically with the variation, stress and change an organisation may contain and experience.

We could begin by developing a framework based on a simple categorisation of HF application according to the direction of influence on, and the relationship to, a given organisational system or project. In this respect, we might distinguish between HF applications that deal with the prospective design (e.g. Hamilton et al.) from those that deal with live systems (Peck). We may further distinguish those HF applications that deal with transition of systems (Owen et al.) from those that deal with the integration of new or evolving parts within systems.

A coherent framework for HF application should account for the various objectives an organisation might have and make the purpose of various HF applications clear and distinct. For instance, for tractable systems, the organisation will need to reduce the possible variation in human work in order to achieve a given risk objective for its operations. In contrast, for the less tractable operation, such as those in decommissioning or emergency management, the organisation may need to enhance the human adaptability that it seeks to limit in engineering design (Owen et al.). The developing framework of the high-reliability organisation and measures of organisational integrity may help in specifying HF application coherently for the whole organisation (Moon and Hamilton).

It is unlikely, however, that nuclear organisations can fully realise the potential of HF for safety if the discipline does not have a strong and influencing position within the organisation's management structure and a sound research and professional base.

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