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UK HPR1000 GDA Project

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Preliminary Safety Report
Chapter 15
Human Factors

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Section Number	Section Title	Page	Content	Category

Table of Contents

15.1 List of Abbreviations and Acronyms

ALARP	As Low As Reasonably Practicable
CGN	China General Nuclear Power Corporation
CPR1000	Chinese Pressurized Reactor
EHF	Engineering Principles-Human Factors
EOF	Emergency Operation Facilities
FCG3	Fangchenggang nuclear power plant Unit 3
GDA	Generic Design Assessment
HBSC	Human-Based Safety Claim
HEP	Human Error Probability
HF	Human Factors
HFE	Human Factors Engineering
HFI	Human Factors Integration
HFIP	Human Factors Integration Plan
HMI	Human Machine Interface
HPR1000 (FCG3)	Hua-long Pressurized Reactor under construction at Fangchenggang nuclear power plant unit 3
HRA	Human Reliability Analysis
I&C	Instrumentation and Control
LCS	Local Control Station
MCR	Main Control Room
ONR	Office for Nuclear Regulation
PSA	Probabilistic Safety Assessment
PSR	Preliminary Safety Report
RSS	Remote Shutdown Station
SAPs	Safety Assessment Principles
SSC	Structures, Systems and Components
TAGs	Technical Assessment Guides

TSC	Technical Support Centre
UK HPR1000	The UK version of the Hua-long Pressurized Reactor

15.2 Introduction

15.2.1 Purpose and Scope

Human Factors (HF) encompasses all aspects of the human interface with the plant design and operation. It is therefore a broad cross-cutting topic that is important to, and is influenced by, many aspects of engineering design, nuclear safety case development and conventional safety. The purpose of this chapter of the Preliminary Safety Report (PSR) is to:

a) Define the overall safety objective for HF in The UK version of the Hua-long Pressurized Reactor (UK HPR1000) project.

b) Provide an outline description of the concept of operations from a HF perspective for the Fangchenggang nuclear power plant Unit 3 (FCG3).

c) Describe the approach to Human Factors Integration (HFI) to be taken for the UK HPR1000.

d) Identify the Human Factors Safety Objectives.

15.2.2 Overall Safety Objective for Human Factors

The overall safety objective for the HF activities in the Generic Design Assessment (GDA) for the UK HPR1000 is to ensure that appropriate HF input is provided to all relevant design, safety case and associated management processes so that the nuclear safety risks associated with human error are As Low As Reasonably Practicable (ALARP). The overall safety objective is therefore concluded as below:

There is a comprehensive programme of HF activities covering the integration of HF into the development of the design for the UK HPR1000, and the associated nuclear safety assessment and management processes, so that the nuclear safety risks associated with human error is As Low As Reasonably Practicable.

This supports the following higher level objective identified in Chapter 1 of the PSR:

‘The Generic UK HPR1000 could be constructed, operated and decommissioned in the UK on a site bounded by the generic site envelope in a way that is safe, secure and that protects people and the environment.’

A number of sub-objectives are also identified in sub-chapter 15.4.1, which support the top level safety objective identified above.

15.2.3 Concept of Operations

The general concept of operations for the FCG3 is for a high level of automation. Plant operation is conducted automatically with some manual actions required during start-up and shutdown operations. Situational awareness of operators during automatic operations is maintained by the requirements for some supervisory operator actions and for operator confirmation of successful implementation of automated sequences.

The overall concept for the Main Control Room (MCR) is based on two Operators with a Supervisor. One Operator has responsibility for the Nuclear Island and one has responsibility for the Conventional Island. There will also be a number of Field Operators, each with responsibility for a specific area of the plant. In the event of a fault condition, a Safety Engineer will also be present in the MCR.

Fault operation procedures must allow the operator to perform the required manual actions in accordance with the time periods claimed in the safety analyses presented in chapters 12 and 13.

15.2.4 Human Factors Engineering Program Management

15.2.4.1 HFE Activities Goals

The Human Factors Engineering (HFE) activities goals in the GDA for the UK HPR1000 are implement 'Human-centered' design. The following items should be included:

a) Personnel tasks can be accomplished within time and performance criteria.

b) The Human Machine Interfaces (HMIs), procedures, staffing qualifications, training, management and organizational arrangements support personnel situation awareness.

c) The design will support personnel in maintaining vigilance over plant operations and provide acceptable workload levels, i.e., minimize periods of under- and over load.

d) The HMIs will minimize personnel error and support error detection and recovery capability, Reference [1].

15.2.4.2 Assumptions and Constraints

An assumption or constraint is an aspect of the design, such as a specific staffing plan or a specific HMI technology that is an input to the HFE program rather than the result of HFE analyses and evaluations. The main assumptions or constraints will be considered in the GDA for the UK HPR1000 includes:

a) The management requirements

The HFE program should satisfy the requirements of the codes and standards (refer to sub-chapter 15.4.2.3).

b) Users' requirements

Users' requirements are one of the important inputs of GDA HFE activities.

c) Plant system design information

The design requirements and scheme of each plant system, such as the configuration of systems, auto level, etc., will affect the HMIs design.

d) Technical limitation

The technique used in different parts of the plant will limit the HFE activities, such as digital technique, computer-based procedures, etc.

15.2.4.3 HFE Activities Scope

The HFE activities scope in the GDA for the UK HPR1000 is as follows:

a) Facilities: the HFE program should cover the MCR, Remote Shutdown Station (RSS), Technical Support Center (TSC), Emergency Operation Facilities (EOF) and Local Control Stations (LCSs).

b) HMIs and procedures: the HFE program addresses the design of safety-related HMIs and identifies inputs to the development of procedures for the operations, accident management, maintenance, test, inspections, and surveillance tasks that operational personnel performs or supervises.

c) Personnel: The HFE program considers operations staffing and qualifications.

15.2.4.4 HFE Team and Responsibility

There is a multi-disciplines HFE team and organization to be responsible for the HFE activities within the scope of this program. The design team as a whole satisfies the professional experience qualifications described in table T-15.2-1.

T-15.2-1 Responsibility and Role of HFE Team and Organization

Discipline	Responsibility
Technical Project Management	In Charge of the HFE team whole work: - develop and maintain the schedule for the HFE design process - provide a central point-of-contact for managing the HFE design and implementation process
Systems Engineering	- provide knowledge of the purpose, operating characteristics, and technical specifications of major plant systems - provide input to HFE analyses, especially function and task analyses - participate in developing procedures and scenarios for task analysis, validation, and other analyses
Nuclear Engineering	- provide knowledge of the processes involved in controlling reactivity and generating power - supply input to HFE analyses, especially function and task analyses

Discipline	Responsibility
	- participate in developing scenarios for task analysis, validation, and other analyses
Instrumentation and Control (I&C) Engineering	- provide detailed knowledge of the HMI design - including control and display hardware selection, design, functionality, and installation - provide knowledge of information display design, content, and functionality - participate in the designing, developing, testing, and evaluating the HMIs - participate in developing scenarios for Human Reliability Analysis (HRA), validation, and other analyses involving failures of the data processing systems - provide input to software quality assurance programs
Human Factors Engineering	- provide knowledge of human performance capabilities and limitations, applicable human factors design and evaluation practices, and human factors principles, guidelines, and standards - develop and perform human factors analyses and participate in resolving identified problems therein
Plant Operations	- provide knowledge of operational activities, including task characteristics, HMI characteristics, environmental characteristics, and technical requirements related to operational activities - provide knowledge of operational activities supporting HMI activities, such as developing HMIs, procedures, and training programs - participate in developing scenarios for HRA evaluations, task analyses, HMI tests and evaluations, validation, and other evaluations
Plant Procedure Development	- provide knowledge of operational tasks and procedure formats, especially as presented in emergency procedure guidelines, and operational procedures of current and predecessor plants - participate in developing scenarios for HRA evaluations, task

Discipline	Responsibility
	analyses, HMI tests and evaluations, validation, and other evaluations - provide input for developing emergency operating procedures, procedure aids, computer-based procedures, and training systems
Overall design/ Reliability/Availability Engineering	- provide knowledge of plant component and system reliability and availability and assessment methodologies to the HMI development activities - participate in Function analysis - participate in the development of scenarios for HMI evaluations, especially validation - provide input to the design of HMI equipment to provide reasonable assurance that it meets reliability goals during operation and maintains the specified level of availability

15.2.4.5 HFE Team Staff Qualifications

The education of the HFE team staff includes several disciplines, such as Ergonomics, Psychological, Statistical Analysis, Process Automation, Electrical Engineering and Automation, Thermal Energy and Power Engineering, Nuclear Science and Technology, Application Chemistry, Heating Ventilation and Air-Conditioning, Environmental Engineering, Chemical Engineering and Process and so on.

All of the HFE team members have the bachelor or the master degree and have at least three years' experience in nuclear power plant design or operations.

15.2.4.6 HFE Issues Tracing

A tracing system is addressed for all the identified human factors issues, including the individual responsibilities for logging, tracking, and resolving it, along with the acceptance of the outcome.

15.3 Human Factors Analysis Methodologies

15.3.1 Human Factors Integration in the FCG3 Design

A comprehensive programme of HF activities has been conducted throughout the development of the FCG3 design (see F-15.3-1), using NUREG-0711, Reference [1] as a basis and consisting of the following elements:

a) Human Factors Engineering (HFE) Programme Management.

b) Operating Experience Review.

c) Functional Requirements Analysis and Functional Allocation.

d) Task Analysis.

e) Staffing and Qualifications.

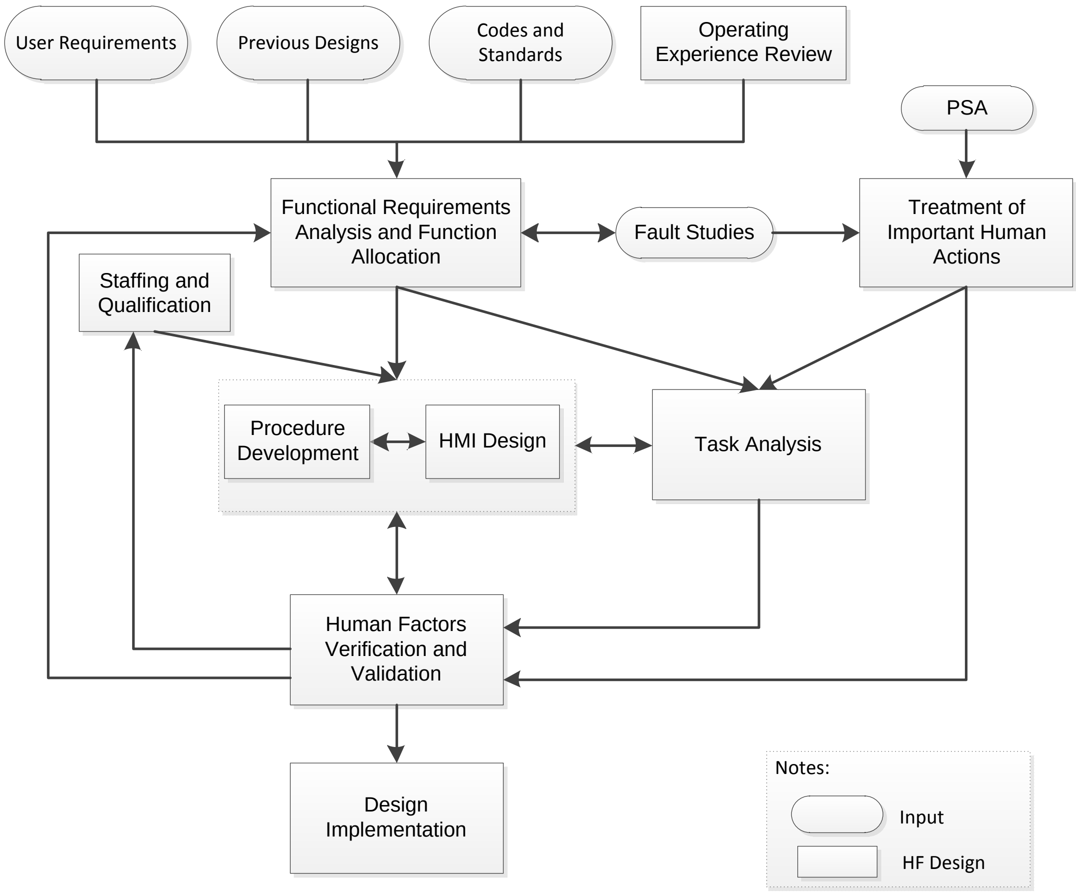
f) Treatment of important human actions (incorporating Human Reliability Analysis).

g) Human Machine Interface Design.

h) Procedure Development.

i) HF Verification and Validation.

The FCG3 design has been developed from the China General Nuclear Power Corporation (CGN)'s fleet design. The operating history of the CGN's fleet and the provision of regular and thorough feedback by operating utilities have provided substantial opportunity to identify and resolve issues, not just in the originating plant or utility, but across the fleet. In addition, international operating experience relevant to the FCG3 technology and equipment has also been reviewed to identify potential areas for improvement. Thus the HF-related aspects of the FCG3 design are underpinned by learning from operating experience of the CGN's fleet in China and other relevant international operating experience.



F-15.3-1 Human Factors Integration in the FCG3 Design

15.3.2 Human Factors Design Approach in the FCG3 Design.

An interactive design approach including 3 main stages was developed for the HFE design as following:

a) Analysis stage

In the analysis stage the following aspect was analyzed:

- Analysis of previous designs of Chinese Pressurized Reactor (CGN's fleets) plants to identify the items needs to be improved.
- Review of operating experiences of Chinese Pressurized Reactor (CPR1000) plants.
- Discussion with final user about the user specified requirements.

b) Design stage

In the design stage the design schemes were modified according to the results of analysis stage.

c) Review stage

In the review stage the preliminary design schemes were reviewed (by mock-up, modeling, prototyping and so on) to make sure the design was correct. If the review result was inacceptable, it will go back to the design stage and modify the schemes according to the review result, and then review again until the result was acceptable.

15.3.3 Human Factors Integration for the UK HPR1000

A programme of HF activities will be established (a Human Factors Integration Plan (HFIP)) that will be integrated with the UK HPR1000 GDA programme and organization to ensure that the output of supporting HF activities is available at the appropriate points in the programme. The basis of the HF programme for UK HPR1000 could base on HPR1000 (FCG3). The overall objective of these activities will be to ensure that:

- The development of HF aspects of the design and safety case is in accordance with the relevant Office for Nuclear Regulation (ONR) Safety Assessment Principles (SAPs), Reference [2].
- Gaps related to HF in the FCG3 design compared to UK requirements are identified and appropriate activities are undertaken to address the gaps.
- HF input is provided to all design and safety case activities where required to meet UK requirements.
- HBSCs are identified and substantiated according to a proportionate approach.

The HFIP could be updated as the project progresses if needed as the project progresses.

Human factors activities will address the following basic considerations of significant human interfaces throughout the project life cycle:

a) Tasks

b) Work environments

c) Personnel

d) Organization and support

e) Human reliability analysis

f) Technical interfaces in GDA

These aspects are addressed in the following sub-chapters.

15.3.3.1 Task Considerations

15.3.3.1.1 Human Activities and Responsibilities

It is important that human activities and responsibilities are defined such that safe and effective system operation is ensured. Human activities and the function of the associated equipment will be complementary and coordinated with each other, so that the overall system can be operated safely and effectively.

15.3.3.1.2 Work Load

Work load is the extent to which ongoing work consumes the mental and physical capacities of personnel, individually or as part of a team. During extended periods of over- or under-load, humans make more errors and/or become less productive. For example, over-loading may occur when attention must be divided among too many tasks, or when rapid response rates must be sustained. Under-loading may occur with monotonous tasks such as monitoring for infrequent events, leading to boredom and inattention. For significant human interfaces, an acceptable working load will be confirmed by analysis, testing, and/or user feedback, Reference [9].

15.3.3.1.3 Human Machine Interface

The design of HMIs has a direct impact on human reliability in conducting actions required to support the safety case. Such HMIs include direct mechanical interfaces with components that incorporate a manual operation facility to support objectives made in the safety case, as well as equipment control system interfaces. For the UK HPR1000, HMI will be developed and validated, and before the HMI design, appropriate HFE design guidelines will be compiled, using experience from the FCG3 project, and taking into account relevant good practice in the UK, covering significant HMI topics, such as MCR and HMI design, and alarms.

Besides MCR, RSS, TSC, LCS and EOF have been designed in HPR1000 (FCG3), and have confirmed the usability for these areas. It will base on UK adults human dimensions to design and validate for UK HPR1000 project.

15.3.3.1.4 Task Analysis

The objectives of task analysis are as follows:

a) Identify the tasks of the personnel performing specific functions;

b) Identify the alarms, information, control and task support and other information required for the implementation of the above tasks.

The tasks selected for analysis represent the full range nuclear power plant operation mode, including startup, normal operation, low-power and shutdown conditions, transient conditions, abnormal conditions, emergency conditions, and severe accident conditions. Combined with the working experience of the previous nuclear projects, requirements analyses of the following aspects need to be considered in the task analysis:

a) Information requirements, such as which alarms and warnings, parameters and action feedbacks are needed to accomplish a task;

b) Decision making requirements, such as the type of the decision (relative, absolute or probabilistic) and the evaluation to be completed;

c) Response requirements, such as the type of actions, task frequency, fault tolerance and accuracy, time available, the location and method to complete the action, etc.;

d) Communication requirements, such as relevant monitoring information or controlled personnel communication;

e) Work load, such as cognitive and physical work load and task intersectionality;

f) Tasks support requirements;.

g) Working space requirements;

h) Situation and performance requirements;

i) Hazard identification requirements.

15.3.3.2 Work Environment Considerations

The following considerations of physical work environments will be addressed to ensure that the design will accommodate personnel and support task performance under all necessary and anticipated conditions. Any differences in requirements for the UK compared with the requirements used as the basis for the FCG3 design will be identified and addressed as part of the management of HF activities through the HFIP, Reference [9].

15.3.3.2.1 Temperature and Humidity

A comfort zone for personnel can be defined by appropriate ranges of temperature and humidity. These factors interact and must be addressed jointly. There will be suitable provision in the design to ensure a comfortable normal working environment, and alternative safe control locations provided for use in the event of normal control locations becoming inhabitable due to a fault, Reference [9].

For the UK HPR1000, the temperature and humidity will base on the FCG3 design, mainly focusing on MCR, RSS, TSC, LCS, EOF and office areas.

15.3.3.2.2 Acoustics and Illumination

Human physiology and task performance are best suited to certain ranges of environmental light and sound. Light and sound may also aid alertness. Adequate levels, spectra, and source positions will be considered during design and confirmed after installation, Reference [9].

For the UK HPR1000, the acoustics and illumination will base on the FCG3 design, mainly focusing on MCR, RSS, TSC, LCS, EOF and office areas.

15.3.3.2.3 Size, Geometry, and Layout

Task performance can be affected by the size and geometry of the workspace (e.g., control room) and by the layout of the workplace (e.g., workstation and its surroundings). The number of personnel and the patterns of communications will be considered. Equipment accessibility and the relating issues such as equipment usability and anthropometry are covered in sub-chapters 15.3.2.1.3 and 15.3.2.3.1, Reference [9].

15.3.3.2.4 Personnel Safety and Environmental Hazards

The approach to conventional safety is outlined in Chapter 25. A proportionate approach will be taken to HF activities in this area, to ensure that the conventional safety risks to personnel are ALARP.

15.3.3.3 Personnel Considerations

The following considerations of human attributes and capabilities will be addressed in HF activities.

15.3.3.3.1 Physiological Limitations and Anthropometry

For strenuous or repetitive manual tasks, the physiological limitations of the human body such as strength, endurance, range of motion, and capability need to be considered. In addition, the workplace layout needs to be compatible with the body dimensions of users in terms of reach distances, seating heights, lines of sight, and physical clearances, Reference [9].

The FCG3 design is based on the Chinese standard for these human physical attributes. A comparison of relevant UK standards with the Chinese standard used for the FCG3 design will therefore be made in order to identify any differences. If any differences are identified with the potential to affect the design or safety case these will be addressed as part of the management of HF activities through the HFIP, Reference [9].

15.3.3.3.2 Cognition

The nature and limitations of human cognition will be considered in design. As compared to machines, humans are more flexible, but less reliable. Thus, tasks involving the continuous monitoring of set points, the performance of repetitive computations, or rapid action are allocated to systems and equipment, Reference [9].

15.3.3.3.3 Knowledge and Abilities

The knowledge and abilities expected of personnel must meet or exceed the applicable task requirements. This is primarily accomplished by technical training and qualification programs, which will be conducted during the Nuclear Site Licensing phase, Reference [9].

15.3.3.4 Organization and Support Considerations

The following considerations are mainly applicable after GDA, as the site-specific safety case is developed, but HF activities during GDA will ensure that these aspects are taken into account, where relevant to GDA design and safety case development. In particular, any assumptions made in support of the substantiation of HBSCs or in design activities will be recorded for validation during the Nuclear Site Licensing phase.

15.3.3.4.1 Staffing

The number of technical staff selected, trained, and qualified will be considered to be sufficient to meet the job requirements, Reference [9].

15.3.3.4.2 Training

Specific knowledge and abilities required for human tasks will be considered to be provided by training and qualification programs, Reference [9].

15.3.3.4.3 Standardization

Standard conventions (e.g., for measurement units, information coding, and device configuration) and standard vocabulary (terminology, abbreviations, and acronyms) will be applied to equipment design, technical documents, and training materials. Standard selections will avoid conflict with existing conventions, Reference [9].

15.3.3.4.4 Procedures

It is expected that the content of procedures will consider how the tasks are to be performed and how errors may be avoided. The potential for procedure violations will be considered too. Procedure documentation is expected to include appropriate explanations, such as the bases for particular actions and expected responses. Operating procedures, in particular, are expected to be verified and validated before issuing, Reference [9].

15.3.3.5 Human Reliability Analysis

Human reliability in performing tasks is influenced by all of the factors identified in sub-chapters 15.3.2.1 to 15.3.2.4. HRA will be conducted for human actions required to support safety in accordance with internationally recognized good practice and using a proportionate approach, underpinned by appropriate task analysis.

Human errors relating to pre-fault tasks, resulting in unrevealed failure of systems required to support safety, or causing postulated initiating events, will be addressed as well as human errors occurring in the response to fault conditions.

Human Error Probabilities (HEPs) required to support the Probabilistic Safety Assessment (PSA) or the derivation of initiating fault frequencies for the assessment of Design Basis Conditions will be determined using appropriate quantitative techniques, taking into account the nature of the human error and task being assessed and factors such as human dependencies. For details, see PSR sub-chapter 14.3.1.1.7 Human Reliability Analysis.

15.3.3.6 Technical Interfaces in GDA

Human Factors is a cross-cutting topic that has significant interfaces with both the design and the development of the safety case. The management of these interfaces is therefore very important and the HFIP for GDA will be integrated with the overall project programme described in Chapter 20.

A significant level of interface will be required with the I&C topic area (Chapter 8) and with the fault studies (Design Basis Conditions, Design Extension Conditions and Severe Accident Analysis, Chapters 12 and 13) and the PSA (Chapter 14).

For I&C, the principal HF focus will be the MCR, TSC and local control panel HMIs. To support the HFIP, a number of HFE design guidelines will be compiled. These will include the control room design guideline, HMI design guideline and local control station design guideline. These design guidelines will base on relevant good practice of the domestic and international standards. These design guidelines will be used to direct the design work of the MCR and local control stations. This process facilitates integration between HF and the plant and system design. Design guidelines may also be produced for other areas, as required.

HBSCs identified from the fault studies and PSA will need to be substantiated using a proportionate approach. This will include qualitative assessment using task analysis techniques and quantitative assessment of HEPs using appropriate HRA methods underpinned by the task analysis. The HF team will work with the fault studies, PSA and relevant engineering teams to ensure that the HBSCs identified can be substantiated. The HRA is an integral part of a completed PSA and will begin early in the design and safety case development process to provide insights and guidance for the development of the design and GDA safety case.

There will also be a HF interface with design development and substantiation activities for Structures Systems and Components (SSC) important to safety. The extent of HF input would be expected to be proportionate to the SSC's significance within the safety case. HF activities would be expected to be concerned with operability and maintainability, including access and inspection and any monitoring, testing or calibration requirements. HF input would also be expected to be provided for project lifecycle activities such as constructability and decommissioning.

HF interfaces are also expected with other safety case areas, such as Internal and External Hazards, Radiation Protection and Environmental. Monitoring and management of dose uptake must include consideration of human capabilities.

HF interface will also be required with conventional safety, where human capabilities and the interface with equipment design and layout influence conventional safety risks. For example, the fire safety strategy will require consideration of alarm response, fire fighting and evacuation. A proportionate approach will be taken to HF activities in support of conventional safety.

Management of Safety and Quality Assurance processes will need to recognize all of the above interfaces and ensure that design and safety case reviews include appropriate HF input through GDA and into the Nuclear Site Licensing Phase.

15.4 Safety Objectives on Human Factors

15.4.1 Human Factors Safety Objectives

15.4.1.1 Method for Identifying Human Factors Safety Objectives

The design of the UK HPR1000 will be based on the FCG3 design, which itself is an evolution of the CGN's fleet in China. In order to identify the higher level objectives for the PSR, the HF team have reviewed the ONR SAPs, Reference [2] and Technical Assessment Guides (TAGs) related to HF [3, 4, 5, 6, 7, 8], and HF design aspects in the CGN's fleet and Hua-long Pressurized Reactor under construction at Fangchenggang nuclear power plant unit 3(HPR1000(FCG3)) projects.

Specifically, identification of the objectives for the PSR was achieved by:

a) Reviewing the SAPs and TAGs related to HF (see sub-chapters 15.4.2.1 and 15.4.2.2) to understand ONR's expectations;

b) Review of relevant standards, codes and guidance (this activity is ongoing, see sub-chapter 15.4.2.3);

c) Review of HF design aspects in the CGN's fleet project in China;

d) Review of HF design aspects in the HPR1000 (FCG3) project in China.

15.4.1.2 Organization of the Objectives

The objectives for PSR (the 'top down' objectives) are organized in two levels. A single high level objective is identified, supported by three sub-objectives. As the design and safety case are developed during GDA, Human Based Safety Objectives will be identified at a more detailed level to support the objectives identified in the PSR (see sub-chapter 15.4.1.5).

15.4.1.3 List of Human Factors Safety Objectives for PSR

The following objectives supports the higher level objective in Chapter 1 of the PSR that 'The Generic UK HPR1000 could be constructed, operated and decommissioned in the UK on a site bounded by the generic site envelope in a way that is safe, secure and that protects people and the environment.'

There is a comprehensive programme of HF activities covering the integration of HF into the development of the design for the UK HPR1000, and the associated nuclear safety assessment and management processes, so that the nuclear safety risks associated with human error is As Low As Reasonably Practicable.

a) The FCG3 design has been informed by learning from the CGN's fleet, including widespread consideration of Human Factors and human error analysis, and regular design improvement through a well-managed program making use of operational experience to identify and reduce the opportunity for human error;

b) The UK HPR1000 will be designed in accordance with relevant standards and relevant good practice in Human Factors to be usable and maintainable for supporting favorable human performance of tasks and minimizes the potential for human error in tasks important to nuclear and conventional safety;

c) Human-Based Safety Claims (HBSCs) which are operator actions with the potential to affect nuclear safety will be identified systematically and substantiated using appropriate human reliability analysis techniques for UK HPR1000.

15.4.1.4 Achievability of Human Factors Safety Objectives

Although at this stage of the GDA the substantiation of the objectives is not expected to be completed, it is necessary that the objectives will be generally achievable. The objectives identified for the PSR are higher level 'top down' objectives. As the GDA progresses more detailed 'bottom up' objectives will be identified and will continue to be identified until the design and safety case have completed their iterative processes, as such the list of objectives for PSR may be modified through GDA. Thus the detailed substantiation of the final objective list will not be finished until the GDA activities are finished.

Notwithstanding this, the objectives identified for the PSR are considered at this stage to be achievable based on the following high-level arguments:

- HF aspects of the FCG3 design have been informed by operational feedback from the CGN's fleet in China, which has been facilitated by the close relationship between operating utilities and the HPR1000 (FCG3) project. International operating experience relevant to the FCG3 technology and equipment has also been taken into account in the development of HF aspects of the design.

- A suitable and sufficient HFIP will be developed for the UK HPR1000, covering the HF activities required to support the development of the design and safety case for GDA, and including appropriate organizational and resource management plans.

15.4.1.5 Identification of More Detailed HBSCs during GDA

As the design and safety case are developed during GDA, HBSCs will be identified at a more detailed level which will support the objectives identified in sub-chapter 15.4.1.3.

Many of these detailed HBSCs will be associated with operator actions required to support the safety case (see (c) in the sub-chapter 15.4.1.3). A systematic approach will be developed to ensure that operator actions important to safety are identified and assessed proportionately. The principal interfaces for the identification and assessment of these operator actions will be the fault studies (Design Basis Conditions, Design Extension Conditions and Severe Accident Analysis, Chapters 12 and 13) and the PSA (Chapter 14).

The scope of operator actions to be covered by the detailed HBSCs will include:

a) Operator actions during normal operational activities, where operator error could result in an initiating event;

b) Operator actions required following a fault, where operator error could result in failure to achieve a safe, controlled state.

15.4.2 UK Requirements for Human Factors

This sub-chapter presents the outcome of the review that has been conducted for the PSR from the ONR's SAPs, Reference [2] and the TAGs relating to Human Factors activities for GDA.

This sub-chapter also includes consideration of codes and standards relevant to HF activities.

15.4.2.1 Review of ONR SAPs Relevant to Human Factors

It is recognized that in the UK, the Health and Safety at Work Act 1974 and Nuclear Installations Act 1965 are the primary governing requirements for any nuclear power plant design and build project. The SAPs, Reference [2] are used by ONR in making regulatory judgments regarding the safety of activities and will therefore be used to inform their assessments during GDA.

The SAPs, Reference [2] directly related to HF are identified in table T-15.4-1, which identifies how the ONR expectation will be met by the UK HPR1000 design.

T-15.4-1 ONR SAPs Related to HF

SAPs	ONR expectation	Approach for UK HPR1000
Engineering Principles-Human Factors (EHF) (as defined in the ONR SAPs).1 Integration with design, assessment and management	A systematic approach to integrating human factors within the design, assessment and management of systems and processes should be applied throughout the facility's lifecycle.	See sub-chapters 15.2.4 and 15.3.2 which describe the HFE programme management for UK HPR1000.
EHF.2 Allocation of safety actions	When designing systems, dependence on human action to maintain and recover a stable, safe state should be minimized. The allocation of safety actions between humans and engineered structures, systems or components should be substantiated.	Appropriate functional allocation and analysis will be undertaken where required to support the development of the UK HPR1000 design and safety case for GDA.
EHF.3 Identification of actions impacting safety	A systematic approach should be taken to identify human actions that can impact safety for all permitted operating modes and all fault and accident conditions identified in the safety case, including severe accidents.	For the UK HPR1000, see sub-chapter 15.4.1.5.

SAPs	ONR expectation	Approach for UK HPR1000
EHF.4 Identification of administrative controls	Administrative controls needed to keep the facility within its operating rules for normal operation or return the facility back to normal operations should be systematically identified.	Administrative controls mainly refer to Technical Specifications, whose purpose is to regulate the operators' actions to ensure the safe operation of unit. Technical Specifications contain requirements of two aspects: technique and management. Technical requirements, for example, operational limits and conditions, will be described in PCSR of GDA stage. Management requirements, for example, plant organization, staff training, will be developed by the future licensee.
EHF.5 Task analysis	Proportionate analysis should be carried out of all tasks important to safety and used to justify the effective delivery of the safety functions to which they contribute.	For UK HPR1000, a proportionate approach will be taken to task analysis undertaken to demonstrate that human actions required to support safety are achievable (see sub-chapters 15.3.2.1.4 and 15.3.2.5).
EHF.6 Workspace design	Workspaces in which operations (including maintenance activities) are conducted should be designed to support reliable task performance. The design should take account of the physical and psychological characteristics of the intended users and the impact of environmental factors.	For the UK HPR1000, it will be ensured that any differences in requirements are addressed (see sub-chapter 15.3.2.2).

SAPs	ONR expectation	Approach for UK HPR1000
EHF.7 User interfaces	Suitable and sufficient user interfaces should be provided at appropriate locations to provide effective monitoring and control of the facility in normal operations, faults and accident conditions.	For the UK HPR1000, it will be ensured that any differences in requirements are addressed (see sub-chapter 15.3.2.1.3).
EHF.8 Personnel competence	A systematic approach to the identification and delivery of personnel competence should be applied.	Requirements for personnel competence and training will be identified by the future licensee. Any requirements for personnel competence and training identified as the GDA safety case is developed and will be recorded for handover to the future licensee, who will be responsible for ensuring that this expectation is met.
EHF.9 Procedures	Procedures should be produced to support reliable human performance during activities that could impact on safety.	Requirements for procedures identified as the GDA safety case are developed and will be recorded for handover to the future licensee, who will be responsible for ensuring that this expectation is met.
EHF.10 Human reliability	Human reliability analysis should identify and analyze all human actions and administrative controls that are necessary for safety.	For GDA for the UK HPR1000, see sub-chapter 15.3.2.5.

SAPs	ONR expectation	Approach for UK HPR1000
EHF.11 Staffing levels	There should be sufficient competent personnel available to operate the facility in all operational states.	Generic single station requirements for staffing levels identified as the GDA safety case are developed and will be recorded for handover to the future licensee, who will be responsible for ensuring that this expectation is met through the nuclear site licensing phase. The implementation of operation staffing and qualification of each type of reactor, the training and evaluation process of staff would be surveyed. The operation staffing and qualification will be demonstrated sufficiently through integrated verification or scenario verification. At last, all of the staff should pass the official examination of nuclear power plant operator which is organized by the supervision department.
EHF.12 Fitness for duty	A management process should be in place to ensure the fitness for duty of personnel to perform all safety actions identified in the safety case.	The future licensee will be required to ensure the fitness for duty of personnel required to perform actions important to safety.

15.4.2.2 Review of ONR TAGs Relevant to Human Factors

The TAGs are guidance for ONR inspectors that can be used in GDA to provide an indication of their more detailed expectations in specific areas. The TAGs that are considered to be particularly relevant to HF activities in GDA are listed in table T-15.4-2. The basic concepts and principles outlined in the guidance in these TAGs will be taken into account in defining, managing and implementing HF activities in GDA.

T-15.4-2 ONR TAGs Related to HF

TAGs Number	Title	Comments/Notes
NS-TAST-GD-058, Reference [3]	Human Factors Integration	Defines expectations for a fully integrated programme of HF activities
NS-TAST-GD-059, Reference [4]	Human Machine Interface	Provides guidance on expectations for design
NS-TAST-GD-060, Reference [5]	Procedure Design and Administrative Controls	Provides guidance on expectations for the identification and substantiation of administrative controls
NS-TAST-GD-062, Reference [6]	Workplaces and Work Environment	Provides guidance on expectations for the design of workplaces and working environments
NS-TAST-GD-063, Reference [7]	Human Reliability Analysis	Defines expectations for human reliability analysis to be conducted in support of the safety case
NS-TAST-GD-064, Reference [8]	Allocation of Function between Human and Engineered Systems	Defines expectations for the demonstration of appropriate allocation of functions

15.4.2.3 Codes and Standards

HF activities in support of the development of the FCG3 design have been conducted by a comprehensive programme using NUREG-0711, Reference [1] as a basis (see sub-chapter 15.3.1).

Control rooms for FCG3 have been designed in accordance with the following international standards:

a) IEC 60073-2002 Basic and Safety Principles for Man-Machine Interface, Marking and Identification - Coding Principles for Indicators and Actuators Sixth Edition.

b) IEC 60960-1988 Functional design criteria for a safety parameter display system for nuclear power stations.

c) IEC 60964-2009 Nuclear power plants – Control rooms – Design.

d) IEC 60965-2009 Nuclear power plants – Control rooms – Supplementary control points for reactor shutdown without access to the main control room.

e) IEC 61227-2008 Nuclear power plants – Control rooms – Operator controls.

f) IEC 61771-1995 Nuclear power plants – Main control-room – Verification and validation of design.

g) IEC 61772-2009 Nuclear power plants – Control rooms – Application of visual display units (VDUs).

h) IEC 61839-2000 Nuclear power plants – Design of control rooms – Functional analysis and assignment.

i) IEC 62241-2004 Nuclear power plants – Main control room – Alarm functions and presentation.

j) IEEE 497-2010 IEEE Standard Criteria for Accident Monitoring Instrumentation for Nuclear Power Generating Stations.

k) IEEE 1023-2004 Recommended Practice for the Application of HFE to systems, equipment and facilities of Nuclear Power Generating Stations and other Nuclear facilities.

l) IEEE 1289-2012 Guide for the application of human factors engineering in the design of computer-based monitoring and control displays for nuclear power generating stations.

For the UK HPR1000, a review of codes and standards applicable in the UK context and other relevant good practice will be undertaken. The scope of this review will not be limited to control room design. It will also address HF aspects of the design of other SSCs important to safety, for example, ergonomic aspects of interfaces with mechanical equipment, and the working environment. These codes and standards and relevant good practice will be compared with the codes and standards used in the FCG3 design in order to identify any gaps with respect to UK expectations. The approach to resolving any gaps identified will then be determined in consultation with the relevant design engineers to ensure the design meets UK expectations.

15.5 References

[1] NUREG, US NRC Human Factors Engineering Program Review Model, NUREG-0711, Revision 3, November 2012.

[2] UK Office for Nuclear Regulation, Safety Assessment Principles for Nuclear Facilities, 2014 Edition, Revision 0.

[3] UK Office for Nuclear Regulation, Human Factors Integration,

NS-TAST-GD-058, Revision 3, March 2017.

[4] UK Office for Nuclear Regulation, Human Machine Interface, NS-TAST-GD-059, Revision 3, November 2016.

[5] UK Office for Nuclear Regulation, Procedure Design and Administrative Controls, NS-TAST-060 Revision 2, November 2014.

[6] UK Office for Nuclear Regulation, Workplaces and Work Environment, NS-TAST-GD-062, Revision 3, ONR, February 2017.

[7] UK Office for Nuclear Regulation, Human Reliability Analysis, NS-TAST-GD-063, Revision 3, April 2015.

[8] UK Office for Nuclear Regulation, Allocation of Function between Human and Engineered Systems, NS-TAST-GD-064, Revision 2, December 2014.

[9] IEEE, IEEE Recommended Practice for the Application of Human Factors Engineering to Systems, Equipment, and Facilities of Nuclear Power Generating Stations and Other Nuclear Facilities, IEEE1023, 2004.