

# Testing HF Requirements to Optimise Human Performance

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## SUMMARY

This paper will cover the approach used to integrate Human Factors (HF) requirements into project testing and commissioning phases of a major nuclear new build project as well as key insights to reliably test the design and tasks involved to optimise human performance. This includes discussion on the importance of deriving good HF requirements, testing these requirements effectively and delves into the HF Verification and Validation (V&V) techniques involved to successfully progress the design project from detailed design into testing and commissioning phases. With the overarching goal to produce a safe and operable facility.

## KEYWORDS

Verification, Validation, Requirements, Testing

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## Introduction

Within high hazard industries a failure in human performance has the potential to lead to significant consequences to the operators and public. People regularly talk about human performance in regard to the “doing” or “sharp end” of a task. However, often human performance is influenced long before we ever start a task – when defining the required role of the operator, throughout the iterative design process, and validating the design through testing. In safety critical operations we cannot just purely rely on people to do the right thing at the right time – we have to provide the environment for them to succeed and part of that is through the task design and design of the equipment and systems they use. Ensuring that the system is designed so that the right thing to do is the easiest thing to do, and then confirming those tasks can be performed as intended.

It is important therefore, to have HF requirements which are well derived and managed, to guide the iterative process from concept to detailed design. Beyond design phases it is crucial to continue building confidence throughout testing that the operator role is adequately supported by the design, and where necessary identify operability issues and adapt the design to optimise human performance.

To ensure that the design meets HF requirements (verification) and for the design to achieve its intended purpose (validation), it is vital to gain reliable evidence by having set testing criteria for each requirement and fully integrate this criterion into testing plans. Embedding criteria into testing plans to reliably verify and then validate the operability of the design is key for ensuring it is optimised to support human performance during operations, maintenance and recovery tasks.

## Why test the role of the operator throughout testing and commissioning phases?

- **Achievability of Tasks** - Testing the role of the operator aims to provide confidence in the operational design via physical demonstration and testing that the required tasks can be achieved. Engineering design requirements help ensure that the equipment functions as

expected and in a reliable manner, and equivalent to this, are HF design requirements which are essential to demonstrate that equipment is feasible to operate and maintain safely.

- **Drive and optimise design changes where required** – Where testing identifies operability issues with the design verification or where functional issues drive changes which impact operability, testing HF requirements and ensuring criteria is accurately tested and validated will ensure the final design successfully meets the requirements.
- **Project de-risking** - If HF requirements are not tested, the project significantly increases the amount of risk it carries into the operational design, as issues are identified late in the process or potentially go unrealised. In worst case scenarios this will lead to an unsafe and inoperable design placing an unacceptable and potentially unachievable amount of reliance on Human Performance.
- **Time, Process, and Cost Saving** - Early testing is the ideal opportunity to confirm that the manufactured design meets HF design requirements. This provides the ability for HF issues to be identified and resolved as early as possible when it is the most timely, simple, and cost effective to make the necessary changes to the design.
- **Regulatory Compliance** - The Office for Nuclear Regulation (ONR) and other relevant regulatory bodies have set conditions which the design of this facility is required to comply with. Validating HF requirements and recording evidence during testing and Commissioning phases is a vital step in demonstrating this.

### **How do we successfully test the role of the operator?**

#### ***Derivation of optimised requirements***

Having the project's set of HF requirements derived through both generic and specific methods provides the means to comprehensively verify and validate all possible design aspects of the system which impact human performance. The two methods are depicted as follows:

- **Generically**, from standards/good practice guides or,
- **Specifically**, from task analyses/HAZOPs/Safety Assessments (e.g., Human Based Safety Claims or Safety Critical Tasks), to support specific elements of the task.

This combination of derivation methods helps to form requirements which enable the operator to achieve all individual tasks and ultimately the task or system goal in a safe manner.

On the major nuclear new build project, HF requirements have been derived early within the project lifecycle and integrated with other engineering disciplines requirements. Through an integrated approach, we were able to ensure:

- HF requirements were worded to enable the design to demonstrate how it would be met, while not restricting the means by which it should be achieved (see following section for more detail).
- HF requirements were treated with equal importance to engineering requirements.
- Requirements were individually identified, tracked and linked to the safety case and engineering safeguards.
- Duplication was minimised and prevented where possible.
- Requirements were assigned to the right people for implementation.
- Communication of requirements is as easy to understand as possible.
- Eased the process to integrate design requirements into testing phases through developing clear test and success criteria.

In addition, should existing requirements be modified or new requirements derived as and when the need arises (e.g., due to changes in operational philosophy, new human-based safety claims from the safety assessments, design changes, etc.), this is easily managed using a HF V&V Plan.

***Characteristics of optimised requirements include:***

- **Worthwhile:** Is the requirement genuinely achieving something in the design or supporting an operator task in some way?
- **Targeted to the audience:** Does the requirement make sense to the individual responsible for implementing it?
- **Genuinely required:** Is it a genuine requirement or guidance? Guidance should be managed separately to support designers in their work.
- **Solution agnostic:** Focus on what the equipment/system needs to do or provide, not how it will be achieved, this helps to ensure relevance even if the design changes and allows designers to identify optimal solutions.
- **Tailored:** Is it relevant to the specific operations and human performance standard required?
- **Measurable:** Are there clear ways of verifying and validating the requirement?
- **Balanced:** Is the requirement trying to do too much or being hyper focused when it could be more generic. Or perhaps the opposite is true, is the requirement too generic which may cause it to become difficult to understand the parameters to fully validate it?

***Develop applicable testing criteria***

From well-defined requirements, HF testing criteria has been developed to be appropriate for each stage of testing based on the planned scope, availability of equipment and elements of the system, and the possible conditions of testing. In collaboration with relevant stakeholders including Engineering, Pre-Operations, Maintenance, and Commissioning teams; how and at what stage testing criteria can be reliably tested has been confirmed. HF design requirements have been added to test plans where applicable, with task conditions accurately replicated as early and as close to the true operating conditions as possible. Successfully replicating conditions will maximise the level of validity in the evidence produced by the test results.

Unlike purely functional Engineering requirements, standard pass/fail criteria is often not suitable to successfully test the majority of HF requirements which focus on assessing the operability of the design. A range of testing criterion types have been identified to be required to effectively test the full range of HF requirements selected for testing. An overview of the testing criterion types implemented into the project's testing scope includes:

- **Manufacturing Confirmation:** Requirements which require confirmation that the manufactured design is accurate to the intended design e.g. confirm the Glove port height is within the ergonomic range; a pass/fail criterion within a set of pre-defined limits.
- **Trial Confirmation:** Other requirements may gain sufficient V&V evidence from testing through appropriately designed test steps. These suitably test the equipment and tasks involved against the criteria to gain the required confidence for that testing stage. An example of this could be a step confirming whether the package has successfully been cut, which is directly linked to an HF requirement concerning the achievability of this action.
- **Operational & Witnessing Subjective Feedback:** For HF requirements that are more operability focused, the most significant method to gain valuable validation evidence is through conducting the tasks under closely replicated conditions and recording live subjective qualitative feedback from the test operators and the witnessing stakeholders present for the test (including HF or Pre-Operations personnel if possible). For testing these

requirements accurately, defined testing conditions are crucial to gain reliable validation evidence.

The level of validation possible to gain will increase throughout the testing and commissioning phases as elements of the built design connects, eventually within the operational environment, at which point the conditions will be fully replicated. At active commissioning the materials to be processed within the facility will be involved as the final step to gain full confidence in the operational process and ability to successfully manage the hazards involved.

It is worth stating at this point that the majority of verification activities have been carried out within the detailed design phase and are captured within the HF V&V plan prior to testing. Verification evidence is necessary to ensure the majority of the design is confirmed prior to initiating the manufacture stage. Subsequent testing phases then focus primarily on the validation of the manufactured design with the aim to gain validation evidence. However, depending on the maturity of the design related to the requirement being tested, verification activities may still be important to complete via early Factory Acceptance Testing (FAT) or even after during Integrated Works Testing (IWT) if required. This is particularly relevant where design changes have occurred.

### **Method used to effectively integrate HF requirements into testing**

To successfully embed HF requirements within testing plans, testing criteria was developed which is realistic considering the availability of equipment and replicability of tasks to the true operational conditions. The HF integration method was developed for this project as follows:

- **Step 1: Selection of HF requirements to test** – All design requirements contained within the HF V&V plan were reviewed to identify those feasible to test at each stage. This screening activity was made in collaboration with the Engineering, Commissioning, Pre-Operations and Maintenance teams and is dependent on the availability and possible setup of equipment, and scope of testing at each testing and commissioning phase.
- **Step 2: Derive test and success criteria** – Test and success criteria was derived for each requirement with any special conditions required to achieve the level of verification and validation expected.
- **Step 3: Integrate HF design requirements & criteria within testing documentation** – In collaboration with test authors, the test steps which were applicable for testing each requirement were identified. To track and manage requirements, unique HF requirement IDs were assigned to individual steps. HF judgement was required to assess whether the inclusion of HF requirements criteria was acceptable. In some instances HF have required further testing or for a completely separate test performed to adequately test the criteria at this phase. This is the case for HF requirements identified to have important tasks associated and/or help to underpin key Operational Preventative Measures (OPMs) critical to maintaining safety.
- **Step 4: HF review of testing procedures** – The HF review of test procedures has helped to ensure criteria has been implemented consistently, testing conditions and pre-requisites are well defined, and the correct input has been provided into the design of the test and individual steps. This input is key for HF requirements to be tested by the expected method and therefore, produce reliable testing results. HF are key stakeholders to the development of testing documents and in order to progress, HF approval is required.
- **Step 5: Tester and Witnesser recording of evidence during testing** – Accurate and reliable evidence recorded during testing. HF validation guidance to support the subjective feedback required of each HF requirement has been provided along with HF briefings to the witnessing team in order to record suitable evidence for HF requirements., HF form part of the Witnessing team present at selected tests to ensure a proportionate and

pragmatic level of involvement. HF have identified specific tests which require HF to attend judged on the importance of assessing the equipment and tasks involved.

**Supporting HF Activities and Deliverables to Optimise Integration**

In addition to integrating HF requirements and criteria into project testing documents following the above process. Further support has been provided to ensure the testing process fully assesses the design’s operability. Supporting activities with stakeholder buy-in have been conducted to produce and implement the following documents:

- **Glovebox setup and equipment use document** – The purpose of this document was to agree and record the Glovebox setup, availability and use of equipment during Factory Acceptance Testing (FAT) and Integrated Works Testing (IWT) to ensure the HF requirements tested will replicate the as built/manufactured design as much as possible.
- **Glove port position assessment** – This document provides a checklist assessment template to evaluate the Glove port positions at the earliest possible stage in testing to confirm positions and make any necessary adjustments to optimise operability. Reach, force, and visibility aspects are assessed in context to the full range of tasks associated with the equipment and components to be interacted with through each port.
- **Guidance for Validation of HF Requirements** – This document provides guidance to the testing team on the method to successfully record validation evidence for HF design requirements being tested when HF are not in attendance.

Table 1 below is an example taken from the validation guidance document to help inform the testing team, including facilitators, operators, and witnesses of the questions and considerations when reach is a relevant factor during testing. The intent of this checklist is to provide an understandable set of considerations applicable, as a guide to record sufficient qualitative evidence when evaluating whether the as built design supports the operator’s ability to reach and manipulate equipment within the Glovebox.

Table 1: Reach Validation Checklist

<b>HF Requirement:</b>	
V-HF-50: The design of gloveboxes shall ensure that equipment to manipulate is within the comfortable zone of reach for the 5th percentile female where practicable for normal, maintenance and emergency procedures.	
<b>HF Criteria:</b>	
Gain subjective feedback from test operators on any issues found to reach equipment and areas of the glovebox involved with the test step.	
<b>Test Witnessing Questions/Considerations:</b>	
1.	<b>Reach all Equipment:</b> Can the tester reach all of the equipment that they need to interact with? Identify the Glove Port and equipment with reach issues to be considered for adjustment.
2.	<b>Task Completion:</b> Can the tester complete the required tasks when having to reach the equipment?
3.	<b>Operation:</b> Can two hands be used to operate equipment where intended?
4.	<b>Additional Testers:</b> Did the tester need any support to perform any tasks (from another tester)? e.g. additional testers required to lift/lower/push/pull. Specify how many if additional required.

5.	<b>Other Users:</b> Do you think other users than the tester may experience issues reaching and/or completing the required tasks? i.e. Someone with different physical characteristics; larger or smaller in stature, with more or less arm reach, larger arm breadth etc. Specify tasks and/or specific parts of tasks which apply.
6.	<b>Body Positioning:</b> Does the tester adopt any awkward body and limb postures to complete the tasks? i.e., leaning, squatting, turning side on to allow more reach with one hand, moving body or arms in unnatural way to reach? Detail each relevant part of the task and what the issue is.
7.	<b>Accidental Operation:</b> Are any issues with accidental operation / touch anticipated due to reach issues experienced?
8.	<b>Replication of Task:</b> Tasks carried out as if on plant? E.g. Level of PPE used. Any operational impact of PPE use e.g., Does the use of PPE create any issues for reaching equipment?
9.	<b>Use of Aid/ Tooling:</b> Is the use of testing aids / tooling required to reach any component? If so, does the designed tooling help the tester reach all of the equipment that they need to interact with and complete the required tasks? Is there any additional tooling needed not previously expected? Any issues with Aid/Tooling used? i.e. hard to use the aid, time consuming, increases difficulty of other task elements etc.
10.	<b>Error Traps:</b> Are there any 'error traps' identified while performing the task?

### Recording of Evidence and Approval of Results

Evidence is recorded within the test procedure document against each step and then signed-off by each required stakeholder. For identified tests an HF representative will be required to confirm and approve the evidence recorded. Where applicable HF subjective feedback is recorded against the test step, and additional notes and assessments will complete the recorded evidence tied into each completed test. Where HF related feedback has the potential to impact the design and operations, formal observations are made, and more significantly any major issues are captured as a formal Test Fault Observation (TFO).

Following completion of the test, a test results approval process is followed, and HF approval is required as a key stakeholder. Observations and TFOs are reviewed, and where possible resolutions are progressed and re-tested prior to the start of the subsequent testing phase. HF review completed test documents, and where HF did not attend, this review provides a vital hold-point to ensure confidence is gained in the validity of the results produced.

Once the process is completed test documents are approved, HF then update the relevant testing sections of the HF V&V plan with evidence including references, and as necessary also update the testing criteria of future testing phases with any changes as a result of the completed tests.

### Key insights and challenges to HFI into testing

A key element to integrate HF testing criteria successfully is to inform the setup and use of the equipment to be tested, achieving as close to operating conditions as possible. To achieve this, true reach distances and physical operability conditions are simulated through attaching a replicated Glove Port mock-up to the temporary testing windows of the Gloveboxes. A range of additional tooling and testing aids have been identified for use during selected tests including operator steps/platforms, as well as Personal Protective Equipment and Respiratory Protective Equipment such as glove combinations and respirators.

Testing as planned, as performed, and as recorded can have greater differences than expected. Many variables impact testing, and this highlights the importance of providing accurate and well detailed pre-conditions for testing and where differences arise, for these to be captured as part of testing to ensure recorded results are reliable. The importance of test wording is a crucial element of this, to ensure that the order, technique and equipment position or state from which tasks are performed are not open to interpretation by the testing facilitator and test operators.

Highly important is to gain multi-discipline buy-in early to the testing criteria demands which are necessary to successfully test HF requirements. If other key stakeholders understand these reasons from the outset, the HF input to testing will result in a much greater impact to validating the role of the operator. Having sought early engagement, the experience of Pre-Operations, Engineering, Maintenance, and Commissioning teams is utilised to confidently gain validation evidence and identify any additional HF related issues.

We have found that although only the functional elements may be tested first, it is natural for observations concerning the operability of equipment to be made early (prior to planned operability testing). To make the most of early opportunities and assess HF requirements throughout the testing process, using operational experience such as the Pre-Operations team can help ensure that HF requirements are assigned and considered to earlier functional test steps which may benefit from their inclusion even if operability is not directly tested as part of the procedure.