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Ergonomic design of control centres —

Part 7: Principles for the evaluation of control centres

Conception ergonomique des centres de commande —

Partie 7: Principes pour l'évaluation des centres de commande

Reference number
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Contents

Page

Foreword ... iv

Introduction ... v

1 Scope ... 1

2 Normative references ... 1

3 Terms and definitions ... 1

4 Requirements and recommendations for evaluation process ... 3
4.1 General verification and validation (V&V) issues ... 3
4.2 Verification and validation plan ... 5
4.3 Verification and validation scope ... 5
4.4 Verification and validation criteria ... 6
4.5 Verification and validation input documents ... 7
4.6 Verification and validation team ... 7
4.7 Verification and validation resources ... 7
4.8 Verification and validation methods ... 8
4.9 Verification and validation measures ... 8
4.10 Verification and validation results ... 9

Annex A (informative) **Checklist for V&V evaluation process** ... 10

Annex B (informative) **Evaluation process** ... 12

Annex C (informative) **Evaluation (V&V) methods** ... 16

Bibliography ... 20

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 11064-7 was prepared by Technical Committee ISO/TC 159, *Ergonomics*, Subcommittee SC 4, *Ergonomics of human-system interaction*.

ISO 11064 consists of the following parts, under the general title *Ergonomic design of control centres*:

— *Part 1: Principles for the design of control centres*

— *Part 2: Principles for the arrangement of control suites*

— *Part 3: Control room layout*

— *Part 4: Layout and dimensions of workstations*

— *Part 6: Environmental requirements for control centres*

— *Part 7: Principles for the evaluation of control centres*

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Introduction

This part of ISO 11064 establishes ergonomic requirements, recommendations and guidelines for the evaluation of control centres.

User requirements are a central theme of this part of ISO 11064 and the processes described are designed to take account of the needs of users at all stages. The overall strategy for dealing with user requirements is presented in ISO 11064-1.

ISO 11064-2 provides guidance on the design and planning of the control centre in relation to its supporting areas. ISO 11064-3 gives all the requirements and guidance on control room layout. Requirements for the design of workstations, displays and controls and the physical working environment are presented in ISO 11064-4 and ISO 11064-6.

The various parts of ISO 11064 cover the general principles of ergonomic design appropriate to a range of industries and service providers.

The users of this part of ISO 11064 are likely to include, for example, project managers, acceptance engineers, purchasers, suppliers and regulatory bodies.

The ultimate beneficiaries of this part of ISO 11064 will be the control centre operator and other users. It is the needs of these users that provide the ergonomic requirements used by the developers of International Standards. Although it is unlikely that the end user will read this part of ISO 11064, or even know of its existence, its application should provide the user with interfaces that are more usable and a working environment which is more consistent with operational demands. It should result in a solution that will minimize error and enhance productivity.

The terms “human factors” and “ergonomics” are used interchangeably in ISO 11064 and are considered as synonyms.

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Ergonomic design of control centres —

Part 7:
Principles for the evaluation of control centres

1 Scope

This part of ISO 11064 establishes ergonomic principles for the evaluation of control centres. It gives requirements, recommendations and guidelines on evaluation of the different elements of the control centre, i.e. control suite, control room, workstations, displays and controls, and work environment.

It covers all types of control centres, including those for the process industry, transport systems and dispatching rooms in the emergency services. Although this part of ISO 11064 is primarily intended for non-mobile control centres, many of the principles could be relevant/applicable to mobile centres, such as those found on ships and aircraft.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 11064-1:2000, *Ergonomic design of control centres — Part 1: Principles for the design of control centres*

ISO 13407, *Human-centred design processes for interactive systems*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1
evaluation process
combined effort of all verification and validation (V&V) activities in a project using selected methods and the recording of the results

NOTE “Evaluation process” is used synonymously with “verification and validation process”.

3.2
human engineering discrepancy
HED
departure from some benchmark of system design suitability for the roles and capabilities of the human operator and/or user

NOTE This may, for example, include a deviation from meeting an operator/user preference.

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3.3
resolution
identification and implementation of solutions to the deviations identified during the verification and validation activities

3.4
situation awareness
relationship between the operator's/user's understanding of the controlled system's and/or process's condition and its actual condition at any given time

NOTE Originally defined by Endsley [4] in an aircraft pilot context as “The perception of the elements in the environment within a volume of time and space, the comprehension of their meaning and the projection of their status in the near future”.

3.5
validity
degree to which an instrument or technique can be demonstrated to measure what it is intended to measure

NOTE 1 Face validity is concerned with how a measure or procedure appears. It answers the question: Does it seem like a reasonable way to gain the information the evaluator(s) are attempting to obtain?

NOTE 2 Predictive validity will tell whether it is possible to predict from the studied performance measure to the real environment.

3.6
validation
confirmation, through the provision of objective evidence, that the requirements for a specific intended use or application has been fulfilled

NOTE 1 Adapted from ISO 9000:2005, 3.8.5.

NOTE 2 See Figure 1.

NOTE 3 This term is often used in conjunction with “verification” and both terms abbreviated to “V&V” (verification and validation).

3.7
verification
confirmation, through the provision of objective evidence, that specified requirements have been fulfilled

NOTE 1 Adapted from ISO 9000:2005, 3.8.4.

NOTE 2 See Figure 1.

NOTE 3 This term is often used in conjunction with “validation” and both terms abbreviated to “V&V” (verification and validation).

3.8
verification and validation plan
V&V plan
plan specifically developed to govern the evaluation process

3.9
workload
physical and cognitive demands placed on the system user(s) and/or staff

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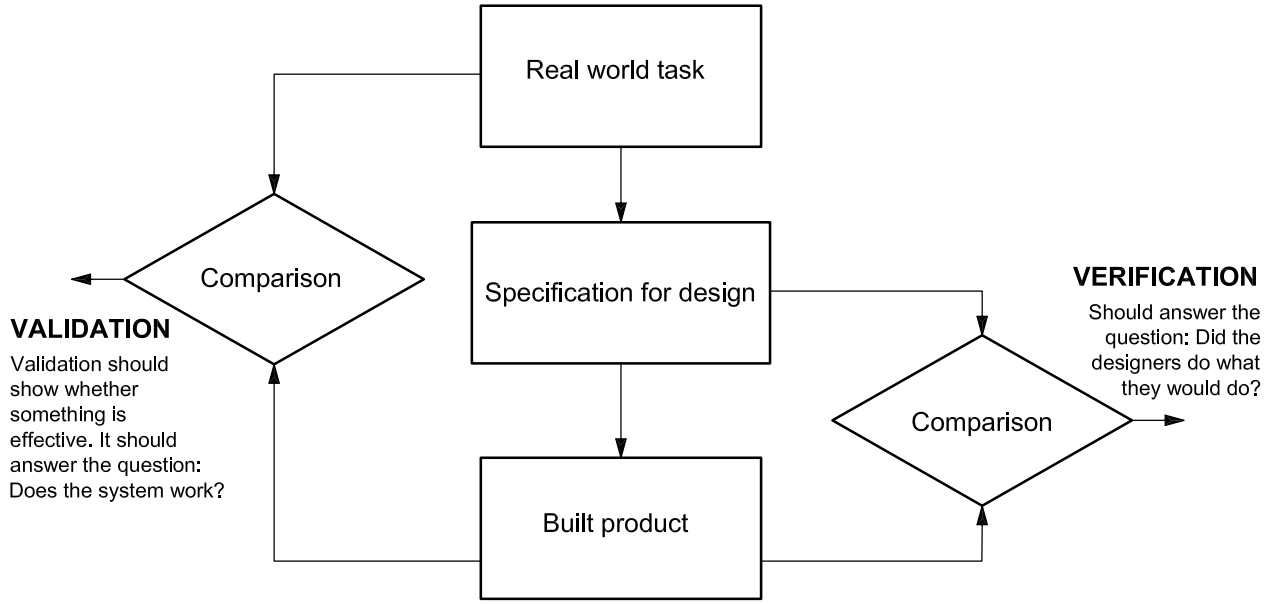

Figure 1 — Role of verification and validation (V&V)

4 Requirements and recommendations for evaluation process

Subclauses 4.1 to 4.10 present general requirements and recommendations for the ergonomic evaluation process. See Annex A for a checklist of these requirements and recommendations.

4.1 General verification and validation (V&V) issues

a) The verification and validation (V&V) activities shall be an integral part of the design process, in accordance with ISO 13407 and ISO 11064-1:2000, Figure 2, and with the Figure 2 immediately below.

b) The V&V activities shall take place throughout the life of a project.

c) Tests shall be done as early in the design process as possible, to allow modifications to be made.

Previous V&V work can be reused under certain conditions. Final determination of what form of V&V is acceptable for evolutionary changes shall be decided in each particular case. For further information, see Annex B.

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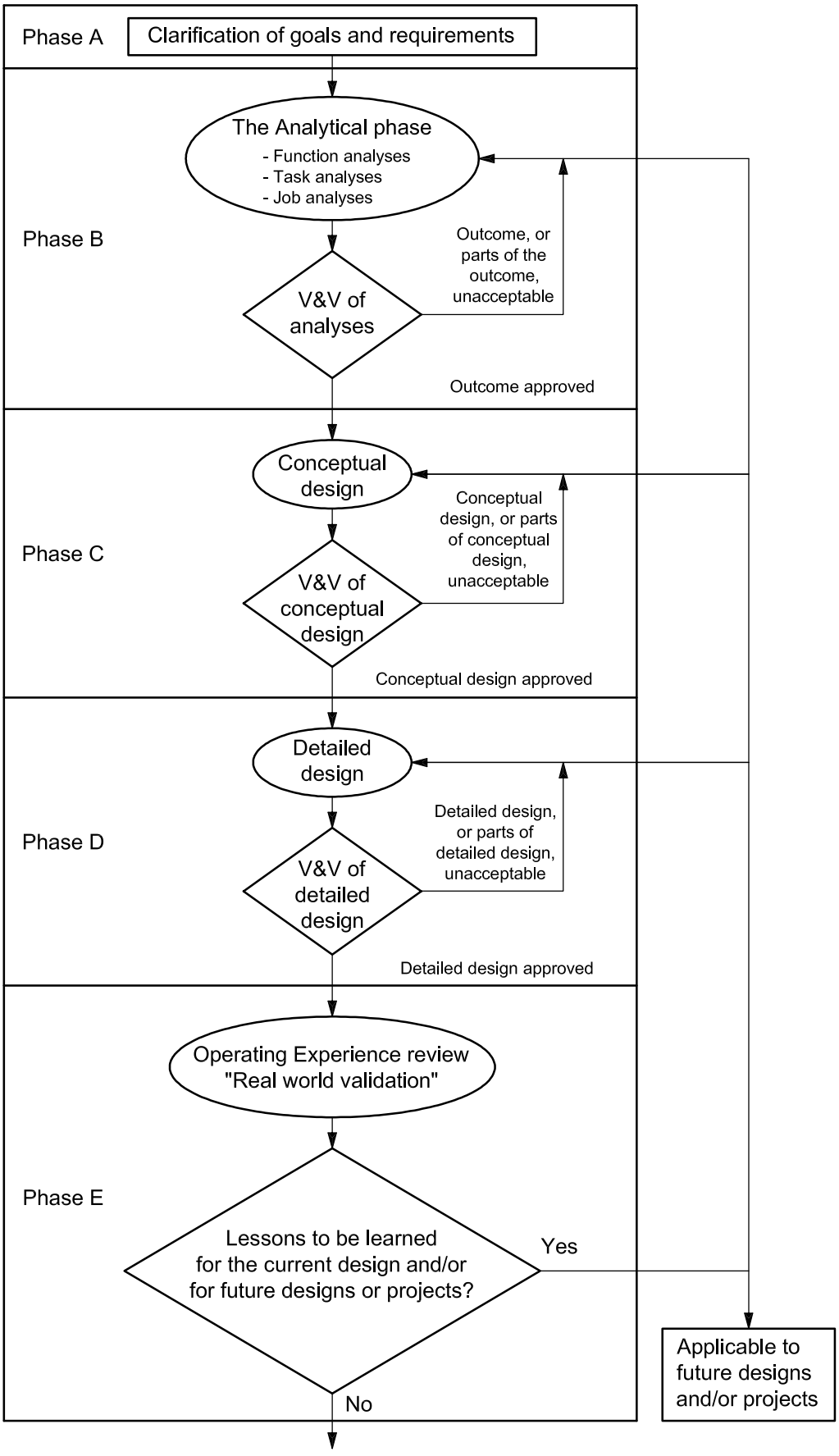

Figure 2 — Integrated V&V in design process

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4.2 Verification and validation plan

a) A V&V plan shall be prepared early in the project and before the V&V work is carried out.

NOTE The plan would be expected to contain, as a minimum, details of the following:

— The objectives for V&V, e.g. maximising human performance, safer operations, human error reduction, enhanced operator support tools, increased job satisfaction and improved production.

— The mandate and terms for V&V.

— The relationship and interfaces of V&V to other elements both within and outside the project, e.g. the design process and the quality assurance programme.

— The V&V team, its primary responsibilities, and resources available to it.

— The approach to be taken to the V&V programme.

— How the process will be applied.

b) The plan should detail the time requirements, relations and dependencies between the tasks within the evaluation process and extend throughout the entire project's duration.

c) The plan for evaluation should have an entry for each topic being reviewed.

d) The plan should document all the criteria, the techniques and tools to be utilised in the evaluation process.

e) The plan shall describe the activities to be performed, and for the verification case, describe each phase to show whether the requirement specification is met.

f) For the validation case, the project should develop performance and safety objectives for the topic under review.

g) Estimates of the resources required to undertake V&V tasks shall be prepared and shall include staff, equipment, accommodation and subjects for trials.

4.3 Verification and validation scope

a) The evaluation scope should be appropriate for the stage of the project at which it is performed.

b) The validation process should challenge the design and ascertain that the system will perform acceptably under a broad range of operating conditions. The validation should include consideration of appropriate scenarios, or working sequences, that should cover normal operation — including a mix of multiple failure events and disturbances, and emergency conditions.

c) There should be written description of appropriate operating situations, adapted to the chosen verification/validation method and the stage of the project.

d) The general scope of the V&V should include all essential facilities defined in the project plan.

NOTE The V&V scope might cover, among other items, the following topics:

— hardware having a human-system interface (HSI);

— HSI software;

— communications facilities;

— procedures (written or electronic form);

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— workstation and console configurations;

— design of the overall work environment;

— training and selection of personnel;

— team working;

— auxiliary shutdown rooms and panels;

— local control rooms;

— local control panels or stations;

— the needs of maintenance personnel;

— other needs of the operators (storage, relaxation areas, rest rooms, etc.).

4.4 Verification and validation criteria

a) The criteria developed shall cover the complete set of ergonomics issues that are relevant to a project.

b) Criteria should be defined for the evaluations of each ergonomic issue and for the objectives that the evaluation is intended to reach.

NOTE 1 The criteria can be derived from the source documents in use for the project:

— performance aspects;

— safety principles;

— availability and reliability requirements;

— operator interface and display principles;

— requirements from applicable standards and guidelines;

— recommendations and requirements from ergonomics literature.

NOTE 2 Performance criteria can be classified into several types, for example:

— requirement-referenced criteria — the comparison of the performance of the system to an accepted performance requirement;

— benchmark-referenced criteria — the comparison of the performance of the system to a benchmark system that is defined as acceptable;

— normative referenced criteria — the comparison of the performance of the system to norms established for the performance based on many system evaluations;

— expert-judgement referenced criteria — the comparison of the performance of the system to criteria established through the judgement of subject-matter experts.

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4.5 Verification and validation input documents

a) The design project's evaluation team should collect all important documentation related to the topic under consideration and used in the design process.

NOTE The documentation will be the basis for the human factors evaluation process.

b) A design project's evaluation team should have access to appropriate documentation.

c) The evaluation team should have access to the members of the team responsible for design and documentation.

d) The evaluation team should have access to a human factors operating experience review.

4.6 Verification and validation team

a) The human factors evaluation team should be independent of, but have access to, the design team. Individuals should not be members of both the design and evaluation teams.

b) The communication between the independent human factors evaluation team and the designers should be supported and stimulated.

c) The human factors evaluation team should be suitably placed in the project organization, i.e., have responsibility, authority and positioning within an organization, such that the commitment to human factors V&V is achieved.

d) The specific expertise represented in a human factors evaluation team should be based on the scope of the evaluation.

NOTE A team might include the following areas of expertise:

— systems engineering;

— architectural design and civil engineering;

— systems analysis;

— instrumentation and control systems;

— information and computer systems;

— human factors engineering/ergonomics;

— facility operation and training (user representatives).

4.7 Verification and validation resources

a) The design project shall supply suitable resources for the evaluation team.

b) Suitable working materials for the conduct of V&V should be prepared.

NOTE Working materials might include the following:

— documentation control;

— control centre components and features;

— measurements (noise, lighting, heating);

— questionnaire and interview records;

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— records of operator responses to specific tests (e.g. simulator based tests or assessments);

— human engineering discrepancies (HEDs), used to identify their location and nature so that follow-up action can be taken;

— resolution of HEDs.

4.8 Verification and validation methods

The following should be considered when determining verification and validation methods.

a) The evaluation method(s) and/or technique(s) used should be systematic and well documented.

NOTE Many human factors evaluation techniques are applicable in a control centre context. A few of the most commonly used techniques are briefly described in Annex C (for more information, see IEEE Std 845[10]). The evaluation techniques may be divided into different categories that are related to the way each technique is used.

b) The evaluation methods should be practical, and effective.

c) Fast and inexpensive evaluation methods should be used wherever possible and the more sophisticated and expensive methods restricted to those evaluations that require them.

4.9 Verification and validation measures

a) The evaluation process should, as far as possible, include quantitative measures of the required features and performance.

NOTE 1 With reference to *verification* and *validation*: in a few cases it might not be possible to derive objective evidence of meeting requirements. For these cases, appropriate subjective assessments could be an alternative.

b) Overall goals such as safety and availability are often difficult to measure and other aspects should be addressed during evaluation of control centres and human-system interfaces. The following are examples of some human performance measures that should be considered:

1) “Compatibility” — the way in which things are presented to operators, and the responses to be expected from the operators, are compatible with human input-output abilities and limitations.

NOTE 2 *Compatibility* means that operators should be able to read displays, reach controls, etc., regardless of overall system objectives.

2) “Understandability” — the information displayed is easily understood and the manual control actions achieve the desired system response.

NOTE 3 *Understandability* means that the structure, format and content of the human-system dialogue results in meaningful communication.

3) “Situation awareness” — the situation is understood and, based on current status and past history, offers the possibility of future predictions.

4) “Controllability” — upon which the operator can base future decisions.

NOTE 4 *Controllability* means to have a certain control of the present situation and knowledge of the history that has led up to the existing status.

5) “Mental workload” measures are based on the hypothesis that the operator has limited cognitive processing capacity.

NOTE 5 Published literature describes *mental workload* as that portion of the operator's limited capacity actually required to perform a particular task.

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6) Measures of “teamwork”.

NOTE 6 The major factors usually listed when describing effective team processes concern its “potency”. This includes social support for team members by helping each other. Other factors include positive social interactions, sharing of workload, communication and cooperation within the team. All these factors are positively related to team effectiveness, productivity and satisfaction.

7) Measures of “Learnability”.

NOTE 7 *Learnability* means that inexperienced users can easily learn how to use the system with little or no need to consult manuals.

8) Measures of “improved performance” such as “effectiveness”, “efficiency” and “satisfaction”.

NOTE 8 *Improved performance* means to make a difficult task easier or enable an operator to accomplish a task that might otherwise be impossible. “Effectiveness”, “efficiency” and “satisfaction” together form the three measures of usability. ISO 9241-11[2] gives details on how to measure usability.

NOTE 9 *Effectiveness*: a human-system environment is effective if it supports the operator (or crew) to improve their performance, e.g. reduction of human error such as procedure violations.

NOTE 10 *Efficiency* means that the resources expended in relation to the accuracy and completeness with which users achieve goals, e.g. task times.

NOTE 11 *Satisfaction* signifies the promotion of maximum comfort and positive attitudes through which users achieve goals.

9) Systems performance measures relevant to facility safety (e.g. by keeping specific process parameters within a certain range).

10) Workstation layout, including dynamic anthropometry evaluations as well as physical positioning and interactions.

4.10 Verification and validation results

a) The results from the evaluation should be recorded and documented, including any deviations from criteria.

b) The process for assessing deviations found in the evaluation should be systematic and documented.

c) All deviations found in the evaluation should be acted on.

d) The evaluation team should check for any risk of side effects of any design changes made because of deviations or non-conformities.

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Annex A
(informative)

Checklist for V&V evaluation process

Requirement/recommendation	Yes	No	N/A	Comments
4.1 General verification and validation (V&V) issues				
a) Are the V&V activities an integral part of the design process?				
b) Do the V&V activities take place throughout the life of a project?				
c) Are tests performed early in the design process?				
4.2 Verification and validation plan				
a) Is a proper V&V plan prepared early in the project?				
b) Does the V&V plan detail items such as time requirements, relations and dependencies between the tasks within the evaluation process, and does this plan extend throughout the entire project's duration?				
c) Does the V&V plan have an entry for each topic being reviewed?				
d) Does the plan document all the criteria, the techniques and tools to be utilised in the evaluation process?				
e) Does the plan describe the activities to be performed and, for the verification case, describe each phase to show whether the requirement specification is met?				
f) Does the project define specific objectives for the V&V of a topic under review?				
g) Have estimates of the resources required to undertake the V&V tasks, including staff, equipment, accommodation and subjects, been prepared?				
4.3 Verification and validation scope				
a) Is the V&V scope appropriate for the stage of the project at which it is performed?				
b) Does the V&V consider all appropriate operating conditions?				
c) Are appropriate operating situations suitably documented considering the chosen V&V method and the stage of the project?				
d) Does the general scope of the V&V include all essential facilities and locations defined in the project plan?				
4.4 Verification and validation criteria				
a) Do the criteria that are developed cover a complete set of ergonomic topics that are relevant to the project?				
b) Are criteria developed for the evaluations of each ergonomic topic?				
4.5 Verification and validation input documents				
a) Has important documentation relevant to the project, and used in the design process, been collected by the design project's V&V team?				

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Requirement/recommendation	Yes	No	N/A	Comments
b) Do the design project's V&V team have permission to access any documentation considered relevant?				
c) Do the V&V team have access to members of the team that have been responsible for design and documentation?				
d) Do the V&V team have access to material on a “human factors operating experience” review?				
4.6 Verification and validation team				
a) Is the V&V team independent of the design team?				
b) Is the communication between the independent V&V team and the designers supported and encouraged?				
c) Is the V&V team suitably placed in the project organization such that the appropriate level of human factors V&V is achieved?				
d) Is the specific expertise represented by the V&V team appropriate for the scope of the evaluation?				
4.7 Verification and validation resources				
a) Does the design project provide adequate resources for the V&V team?				
b) Have suitable working materials for the conduct of V&V been prepared?				
4.8 Verification and validation methods				
a) Are the evaluation method(s) and/or technique(s) used systematic and well documented?				
b) Are the evaluation methods practical and effective?				
c) Are the evaluation methods appropriate?				
4.9 Verification and validation measures				
a) Does the evaluation process include quantitative measures for the required features and performance?				
b) Have other measures of human performance been considered?				
4.10 Verification and validation results				
a) Are results from the evaluation recorded and documented, including any deviations from criteria?				
b) Is the process for consideration of deviations found in the evaluation systematic and documented?				
c) Have all deviations found in the evaluation been acted on?				
d) Have checks been carried out for side effects of any design changes arising from deviations or non-conformities?				

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Annex B
(informative)

Evaluation process

B.1 Use of existing V&V information

Where evolutionary changes are being made relevant information can already exist in earlier design documents, procedures, and operation experience. All together, these can constitute an important pre-validated data set. This data set can be used to meet some of the requirements of the V&V process, although issues such as the degree of change and the quality of existing material must obviously also be taken into account. IEC 61771[9] notes that the V&V activities need to be tailored to the particular needs and circumstances of individual projects. The basic framework for carrying out a V&V is, however, constant, i.e. the stages of preparation, evaluation and resolution are retained:

a) preparation (to prepare the V&V);

b) evaluation (to actually perform the V&V);

c) resolution (to identify and implement solutions to the deviations identified during the V&V).

The additional work that does, or does not, take place under these headings should be justified and documented.

Two important aspects when deciding the V&V requirements for projects of this nature are the “degree of innovation” and the possibility of “qualification by similarity”. The *degree of innovation* relates to those areas of innovation in the change and concentrates V&V activities on them. The degree of innovation varies along a continuum from a replica of an existing design, which would require very little V&V, to an evolutionary design requiring selected V&V activities, to an advanced design requiring the full scope of V&V activities. For evolutionary changes, V&V activities can be concentrated on the areas of change and their integration with existing, proven features of the design.

In addition, the potential to affect or influence risk levels should be considered. Existing safety analyses can help here.

B.2 New V&V information

For a control room upgrade, there is a need to verify and validate new and innovative aspects, including their interaction with the existing facility. A number of issues relevant to the evaluation process for evolutionary changes can be identified, including

— use and consideration of current and previous change programmes and their objectives and philosophies (use of existing documentation),

— consideration of the possible effects of the change on other aspects of work and organizational factors,

— the effect of the changes on training requirements, simulators, procedures and other relevant elements,

— the way changes will be introduced and whether parallel use of old and new systems is desirable for V&V, and

— whether a simulator facility is available where appropriate V&V can be undertaken.

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B.3 Changing nature of facility design and control room tasks

Changes in control centre systems and equipment can affect the role of operators and their tasks both during normal operations and during emergencies. Some relevant and continuing trends include

— greater use of automation,

— a shift of the operator's role from active involvement to monitoring, supervision, and backup of automated systems,

— greater centralisation of controls and displays, both on a station/facility basis and within the control room,

— use of large displays in the control centre that allows for a shared viewing of high-level or summary information and critical parameters,

— a shift of the operator's primary interface — from direct interaction with components to interaction with a data based system,

— increased use of integrated displays and graphical displays, and

— greater use of information-processing aids and decision-support aids.

NOTE If the operator's role has changed in any of these ways, it will be more difficult to argue for qualification by similarity or to claim that the degree of innovation is small.

These trends affect the design, and equipment, in both new facilities and existing control centres. There could be a range of technologies and solutions for the design of the human–system interface at any one location — even for new control centres. In an existing facility there could be a range of degrees of upgrading. These changes mean that any ergonomics programme, and V&V of it, must allow for a diversity of approaches to control and display.

New problems can arise because there is a potential to create additional types of human error and to reduce human reliability in novel ways. Because these tend to be of a different kind from those found in a conventional control centre, they are at first less obvious and less likely to be understood, or even recognised. The ergonomics programme must address these issues and resolve them. The following are some of these new threats to human reliability.

a) Lack of knowledge

Cognitive issues are emerging as more significant than the physical ergonomic considerations of control centre design which have heretofore dominated the design of conventional interfaces, and indeed ergonomics as a subject.

b) Changes in function allocation

Increases in automation have tended to result in a shift from physical workload to cognitive workload. As a result, there are dangers such as loss of vigilance, loss of situation awareness, and eventually, loss of a full understanding of the processes as the operator is taken more and more “out of the loop”.

c) Changes in cognitive implications of designs

Information tends to be more “pre-digested” and is resident on a workstation or computer system rather than physically located in a room; there is a greater quantity of information and an additional burden in operating the interface equipment. These lead to a greater need to specify system requirements in cognitive rather than physical terms. This requires techniques such as cognitive task analysis.

d) Changes in skill demands

Although systems are increasingly automated, they also create new, usually highly skilled tasks for operators. Operators must understand and evaluate the performance of automatic systems, or even take over from them when they fail. It is difficult to see how this level of skill can reasonably be expected of operators, when the same automation has made their daily tasks more boring and monotonous.

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These points make clear that the changing nature and equipment in control rooms itself changes the roles, functions and tasks of the control centre and the staff within it. This in turn puts requirements on the kind of ergonomics work that is needed.

In response to these problems, many organizations have begun to look more seriously at the implications of advanced control centre systems. It is often difficult to set pass/fail criteria or to prescribe methods in advance for some of these new problems. There has consequently been an increased emphasis on the user organizations/utilities giving evidence of a design process and an evaluation process that can stand up to scrutiny and create confidence that a design is satisfactory.

B.4 Sources of confidence in a design

When it comes to human factors, it is important that

— the design follows accepted human factors principles,

— the design supports the performance of the operators,

— the design supports the reliability of operators, and

— the design is resilient to changes and upgrades.

V&V of the human factors aspects of a design is just one source of confidence that a design is satisfactory. There are several sources of evidence for the efficacy of the human factors design as shown in Table 1.

Further confidence in a design can be gained by a detailed test programme of the actual facility and through successful operation of it. The record of operation can also be a source of validation early in the design process for the next similar design or upgrade.

Table B.1 — Types of information for assessment of human factors engineering (HFE) adequacy

Type of evidence	Minimal evidence	Best evidence
Planning of human factors activities	An HFE design team, a programme plan and methods for doing the work	A qualified HFE design team with all the skills and resources required, using an acceptable HFE programme plan
Design analysis work	Function requirement analysis, task analysis, task synthesis, assessments of alternative technologies	Results of appropriate HFE studies, analyses that provide accurate and complete inputs to the design process and V&V assessment criteria
Record of the design	Specifications and descriptions of designs	Designed using proven technology based on human performance and task requirements incorporating accepted HFE standards and guidelines
Verification and validation of the project	Compliance with HFE guidelines and project specifications, operation of the integrated system under actual or simulated conditions	Evaluated with a thorough V&V test programme throughout the project
Use of feedback from other systems	Simple collection of operational experiences from earlier projects or systems	Performance of a comprehensive operational experience review

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B.5 Timing of V&V within design process

It is difficult to find guidance on when in the design process V&V is best applied. Historically there has been a tendency to focus on V&V at the end of a project — after the design work has been completed. More recently, there has been general agreement that V&V should be more iterative and integrated into the design process, although guidance as to exactly when and how often V&V should be carried out is less clear.

It is proposed that lower fidelity test-beds are used for addressing human performance issues much earlier in the design process to allow modifications to be made with minimal effect on the overall HSI system. It is suggested that use is made, for example, of different grades of modelling technology and part-task simulators comprising both individual and partially integrated sets of prototype components. Also dynamic simulations of selected parts of the process may be used. These simulations should be performed as soon as they become available.

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Annex C
(informative)

Evaluation (V&V) methods

C.1 Applicable techniques

In a control centre context many different human factors evaluation techniques are available. No single technique can usually fully handle the problem. This leads to the use of a combination of techniques.

Some of the most commonly used techniques are briefly described in this annex (for more information, see reference [10]). This annex contains only a few examples and is not intended to present a complete list. The evaluation techniques listed below are divided into five categories, according to the way in which each technique is used:

— paper and pencil techniques (see C.2);

— observational techniques (see C.3);

— expert opinion techniques (see C.4);

— experimental techniques (see C.5);

— physical measurement techniques (see C.6).

C.2 Paper and pencil techniques

No actual performance observation is required when using paper and pencil techniques. No prototypical hardware/software is required for most of these methods and the outcome can be a simple accept/reject decision or a ranking.

C.2.1 Ergonomics checklist

A very common technique is the use of a checklist to verify that a design meets certain criteria. A checklist can be used to best evaluate issues related to compatibility. This approach is most applicable during the design process but can be used in a confirmatory fashion.

The technique is easy to use and has high face validity when applied properly. It is very sensitive to those characteristics of systems with easily measurable parameters such as height and colour. The cost of using a checklist is low but its output tends to be categorical.

C.2.2 Historical review

This technique involves the examination of historical records related to the performance of systems that are identical or similar to the system under evaluation. In certain application areas this technique typically involves the use of significant event reports or incident reports, trip reports, operational logs, interviews with operators, etc.

Historical review is most useful for evaluating issues related to system effectiveness in the real setting where the system performance can be evaluated during operation. The face validity is high; however, the predictive validity is dependent on the data available for review and the similarities between historical system applications and the proposed new application. Its output tends to be qualitative.

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C.2.3 Task analysis

Task analysis is the name given to any process that identifies and examines the tasks that must be performed by users when they interact with the system(s) to be evaluated. Task analysis is often considered to be a primary system's design tool, but can also be used as an evaluative instrument. However, it is necessary to thoroughly consider the suitability of using task analysis for evaluation if the technique has been used as a design tool.

Task analysis should be used early in the design process to address issues of compatibility and understandability. The technique may be time consuming if done in enough detail to be useful. It is manpower intensive and, thus, moderately to very expensive. The output of task analysis is normally used as the basis for further evaluative analysis. It is sensitive to most design concerns, with the exception of crew interactions and time dependencies. Task analysis is capable of identifying subtle human–system interaction problems, and its output is a mixture of qualitative and quantitative data.

C.2.4 Logic tree application

Probabilistic risk assessment (PRA) and human reliability assessment (HRA) belong to this category. They are used primarily to estimate human error rates and in particular to identify dominant or most likely accident sequences.

Their application is the evaluation of the effectiveness of existing or planned systems, and is most useful in the design process when prediction of the safety effects of a new or revised system is of interest. The techniques have moderate face validity.

C.3 Observational techniques

The evaluator(s) examine operator performance on the system to be evaluated using observational techniques. One major factor to be considered is the setting in which the observation takes place. The setting has an impact on the cost and ease of use of the technique. Three examples of basic settings are

— mock-ups,

— full-scope simulators, and

— real environment.

C.3.1 Walk-through/talk-through

The most widely used observational technique is the walk-through/talk-through technique. The technique consists of having potential users of the system under test “walking and talking through” (in the sense of physically showing and verbally describing) one or more of the tasks that will be done using that system when it is operational. A walk-through/talk-through is used during the design process, after a prototype system is available.

The face validity is very high, and the predictive validity is limited depending on the similarity between the test condition and the real environment. Likewise, the cost of this technique is dependent on the facilities in which it is conducted. The technique provides qualitative output.

C.3.2 Time line analysis

Time line analysis is very similar to the walk-through technique, but it is used to determine the time required to perform the tasks related to the system under test and their interdependence. Time line analysis can be conducted in any of the settings described earlier. The data-taking requirements are more stringent, because every action must be timed to a reasonable degree of accuracy. The technique can be used either in the design environment or in an operational setting. The best condition is, however, in a realistic and dynamic setting.

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Time line analysis is resource intensive and expensive. It has high face validity and the predictive validity is usually high. The output is quantitative and is as precise as the method used to measure the times involved. The technique is valuable since it can identify situations where the operator has to perform two or more actions simultaneously. It is not particularly easy to use due to the need for precise data collection.

C.3.3 Automated performance tracking

This technique combines some features of walk-through and time line analysis. Automated performance tracking requires a part-task or full-scope simulator to collect performance data while users interact with the system under test. The automated performance tracking system records all control and switch manipulations with time tagging. The technique's weakness is the vast amount of recorded data that must be analysed to provide any meaningful evaluative information. The technique can be used only with functional hardware. Its face validity is high and it is a non-intrusive technique.

The face validity of automated performance tracking is normally high, again dependent on the similarity between the test environment and the real task situation. This technique is the most expensive due to the test system requirements.

C.4 Expert opinion techniques

Expert opinion consists of soliciting opinions from individuals with expertise in a particular content area that relates to the system being evaluated. The individual techniques described below are all designed to make expert opinions more objective and precise.

C.4.1 Delphi technique

The Delphi method is a consensus technique that should be used to estimate whether a human–system environment is adequate. The method develops a scale that can be used as a continuum for any performance related characteristic (error probability, display readability, understandability, etc.) of the system. The technique uses surveys (questionnaires) that are filled out by the experts at their own locations. The analyst collects and collates the responses, then sends out a second round of surveys detailing the opinions that were received (without identifying the respondents). This process is repeated until a consensus is reached.

The technique is useful for a design process when no equipment exists. The output is both qualitative and imprecise; nevertheless, the technique can quickly highlight likely extreme values in a performance measure. The predictive validity is not particularly high, although this depends very much on the experience of the experts used. This is also valid for the face validity. The technique has low costs.

C.4.2 Nominal group technique

This technique is similar to the Delphi technique since multiple experts estimate how a particular human–system environment falls on a scale of one or more continuums that are related to the system's design characteristics.

The major difference between this technique and the Delphi method is that this technique strives for a consensus of judgements in face-to-face meetings. Special precautions have to be taken to ensure that the consensus is not swayed by one individual. In other respects the features of this technique are very similar to those of the Delphi method.

C.4.3 Paired comparisons

There are several variants of paired comparison techniques; however, the basis for these types of techniques is to present each expert with two of something and pose the question as to which of the two is *the greater* (larger, brighter, more probable, etc.) This procedure is repeated for all possible pairs of the items of interest in the evaluation. The judgements are then sorted and compared to determine the judgement scale and dimension. Paired comparison techniques are limited to relatively imprecise, qualitative data. The outcome in terms of data is more reliable than data from the Delphi and nominal group techniques, but paired comparison is more expensive.

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C.4.4 Ratio estimation

In ratio estimation technique, the experts are not asked to make absolute numerical estimates or to compare two things on a relative scale, but to judge whether one thing is either half or twice as great as one item of the set that has been designated as the standard. The instructions to the experts require them to make ratio judgements. The data collected by the ratio estimation technique are much more quantitative compared to other expert opinion techniques; nevertheless, the shortcomings are the same.

C.5 Experimental techniques

All experimental techniques may be used to measure statistically significant differences among candidate human–system environment designs in a laboratory setting or a simulator. They can also be used for validation of a single human-system environment. These include such commonly used methods as interviewing and questionnaire completion.

The distinguishing feature of experimental techniques is the requirement to tightly control all sources of performance variation. This necessitates rather large and well-balanced pools of potential users, very well controlled settings, and sophisticated data recording. The techniques are preferably applied during design, but need careful planning, are time consuming and very expensive. Their face validity is generally low because of the requirement to reduce extraneous sources of performance variation, task complexity and realism. For the performance that is measured, these techniques are usually sensitive. Their output is quantitative, but usually categorical.

C.6 Physical measurement techniques

Where appropriate control room environments exist, physical measurements can be taken in relation to key features, including

— control room layout and dimensions,

— workstation dimensions and sizes,

— thermal conditions,

— air quality,

— lighting,

— acoustics, and

— vibration.

These measurements taken can then be compared to environmental and design specifications.

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Bibliography

[1] ISO 9000, *Quality management systems — Fundamentals and vocabulary*

[2] ISO 9241-11, *Ergonomic requirements for office work with visual display terminals (VDTs), Part 11: Guidance on usability*

[3] ANSI/AIAA G-035-1992, *Human Performance Measurement*, Washington D.C., 1993

[4] ENDSLEY, M.R. (1988). *Design and Evaluation for Situation Awareness Enhancement*. In Proceedings of the Human Factors Society 32nd Annual Meeting)pp. 97-101). Santa Monica, CA, Human Factors and Ergonomics Society

[5] FINK, A., Ed., (1995). *How to measure survey reliability and validity*, v. 7. Thousand Oaks, CA, Sage

[6] *Handbook of Human Factors and Ergonomics*, (1997). Second Edition, G. Salvendy, Ed., John Wiley & Sons, Inc., New York, NY

[7] *Handbook of Human Factors Testing and Evaluation*, (1996). T.G. O'Brien and S.G. Charlton, Ed., Lawrence Erlbaum Ass. Publishers, Mahwah, New Jersey

[8] IEC 60964, *Design for control rooms of nuclear power plants*

[9] IEC 61771, *Nuclear power plants — Main control-room — Verification and validation of design*

[10] IEEE Standard 845, *Guide to Evaluation of Human-System Performance in Nuclear Power Generating Stations*

[11] IEEE Standard 1023, *Guide for the Application of Human Factors Engineering to Systems, Equipment, and Facilities of Nuclear Power Generating Stations*

[12] Interim DEF STAN 00-25 (Part 4, Part 12)/Issue 1, Ministry of Defence, UK, 1989, *Human Factors for Designers of Equipment. Part 4: Work Place Design*. Glasgow: Ministry of Defence, Directorate of Standardisation

[13] NUREG/CR-6393, 1996, *Integrated System Validation: Methodology and Review Criteria*. Washington: U.S. Nuclear Regulatory Commission Office of Nuclear Regulatory Research. Authors O'HARA, J., STUBLER, W., HIGGINS, J., BROWN, W

[14] NUREG-0700, Rev.2, 2002, *Human System Interface Design Review Guidelines*. Washington DC: U.S. Nuclear Regulatory Commission, Office of Nuclear Regulatory Research

[15] NUREG-0711, Rev.1, 2004, *Human Factors Engineering Program Review Model*. Washington DC: U.S. Nuclear Regulatory Commission, Office of Nuclear Regulatory Research

[16] O'DONNEL, R.D. and EGGEMEIER, F.T. (1986). Workload assessment methodology. In K.R. Boff et al Eds., *Handbook of Perception and Human Performance,* Volume II*. Cognitive Processes and Performance*. John Wiley, Chapter 42, New York

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