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# THE USERS CENTERED DESIGN OF A NEW DIGITAL FLUOROMETER

**Marcos S. Farias, Isaac J. A. L. dos Santos, Claudio H. S. Grecco, Paulo S. Pedrosa, Carlos M. Colthurst and Andre P. Szabó**

Instituto de Engenharia Nuclear (IEN / CNEN - RJ)
Caixa Postal 68550
21945-970 Rio de Janeiro, RJ
msantana@ien.gov.br
luquetti@ien.gov.br
grecco@ien.gov.br
pedrosa@ien.gov.br
mcdonald@ien.gov.br
szabo@ien.gov.br

## ABSTRACT

The fluorometer is the equipment used in chemical analysis laboratories, research institutes and nuclear fuel cycle companies. This equipment measures an unknown amount of uranium in ores, rivers, etc. The fluorometer functioning is based on the uranium fluorescence when submitted to the ultraviolet radiation incidence. The fluorescence is measured by an electronic optic system with optics filters, photomultiplier tube, and a current amplifier. The user centered design involvers the user in the product development in all phases of the design process. Users are not simply consulted at the beginning of the design process and evaluated the system at the end; they are treated as partners throughout the design process. The user centered design emphasizes the needs and abilities of the users and improves the usability of the equipment. The activity centered design emphasizes the development of the equipment with a deep understanding of the users activities and of the current work practices of the users. The aim of this paper is to present a methodological framework that contributes to the design and evaluation of a new digital fluorometer towards an approach related to the users and their activities. This methodological framework includes users-based testing, interviews, questionnaires, human factors standards and guidelines, the users activity analysis and users satisfaction questionnaire.

## 1. INTRODUCTION

The user centered design is a process for designing products that meet the needs of the user. An important concept of users centered design is that usefulness and ease-of-use can be ensured only if users are actively incorporated in the equipment design cycle. Representative groups of users are exposed to the equipment at various stages in development, in a variety of testing, evaluation and interviewing situations. The user feedback obtained is then used to refine the design, with the result serving as input to the next interaction of design process. If the involvement of the users occurs late, alterations will be required at the late stage of the development, incurring delays to the design process or additional cost in re-design [1].

The human factors engineering (HFE) is the application of knowledge about human capabilities and limitations to plant, system and equipment design, ensuring that the plant, system design, human tasks and work environment are compatible with the sensory, perceptual, cognitive and physical attributes of the personnel who operate, maintain, and support it [2]. One of the purposes of the HFE analysis is to identify human-system interfaces problems and to propose improvements. Achieving the goals of the human factors engineering program within a system engineering perspective requires incorporating the requirements related to the users into the process. The design of the equipment should consider the human as an element of the system in terms of operators, maintainers, manufacturing personnel, training personnel, for the purpose of understanding the human-system integration issues and ensuring that the products are maintainable, and usable [3].

Ergonomics is an inter-disciplinary research field that focuses on improving the functioning of the human–technology interaction with regard to safety and efficiency. This is accomplished by taking into account the strengths and weaknesses of human performance. The goal of the ergonomics is to achieve the best possible match between the products and the users, in the context of the work task to be performed. The incorporation of the ergonomics in the design of a equipment offers a lot of opportunities for improvements with regard to system effectiveness, efficiency, reliability and safety.

The involvement of the users in the development of a new system or equipment is a key issue in the user centered and in the activity centered approaches. The overall goal is to encourage and to support work force participation in the analysis, redesign and evaluation of their own tasks, workplaces, and tools by applying different participative methods and techniques. The interviews, user-based testing, questionnaires, expert reviews, surveys, checklists, users activity analysis, usability tests, human factors standards and human factors guidelines are useful methods in order to include end-users in the development process.

The aim of this paper is to present a methodological framework that contributes to the design of a new digital fluorometer towards an approach centered on the users and on their activity. This methodology includes the following methods: task analysis, user-based testing, usability tests, interviews, questionnaires, human factors standards and guidelines, user activity analysis and user satisfaction questionnaire.

## 2. THE PRINCIPAL METHODS APPLIED TO THE USERS AND ACTIVITY CENTERED DESIGN

A variety of methods can be used to guarantee the involvement of the users and to validate the allocation of their requirements in all phases of the design process of the digital fluorometer.

Operating experience review is performed to understand current work practices, operational problems and issues in reference or similar designs that may be addressed in the new design. It will include both documented and undocumented sources, including event reports, interviews, talk-throughs and walk-throughs. The purpose of the interviews is to understand current work practices and to identify positive and negative features of the current design. Also, if a similar HSI has been implemented for a different function or system, its operating experience and potential applicability for the new design should be determined from interviews and talk-throughs and walk-throughs. Visits to laboratories, research institutes and other facilities that use similar equipments are highly recommended. Interviews and discussions with users can be a very good way to become more familiar with the technologies, to understand the benefits that can be achieved, and to take advantage of the lessons that have been learned.

The task is what the organization assigns to the person with a purpose [4]. Tasks can be represented by operations and plans. The operations are actions done by operators within a system. Plans are the conditions which are necessary to undertake the operations [5]. The task analysis produces a summary of actions as they have been carried out by the users. It describes the task steps, the actions to be performed, such as valve/pump operations, and the persons that have to perform the actions.

The results of the interviews depend on how the interaction between interviewers and interviewees takes place. The interviewer has to encourage the interviewee and increase his/her confidence in the research to get reliable results. Structured interviews are useful for obtaining simple information, rather than complex opinions. Interviews can also have open questions, requiring more effort from the interviewer to interpret the answers. Less structured interviews with open questions are more appropriate for address inherently complex issues, where ambiguities in the questions or answers can be clarified through the interactions between interviewers and interviewees.

In a walk-through and a talk-through, users perform selected activities and provide information to the HFE analyst either in response to questions from the analyst or as a narrative of their thoughts as they carry out their actions. When users verbalize what they are thinking, as they performing the task or interact with the HSIs, they may reveal the strategies they use, the resources they require from the interface, and their expectations about how the resources will be made available. It will also draw attention to points in the interaction where the design of the interface does not complement the user's goals.

Questionnaires provide a structured way to obtain information. Questionnaires can investigate the operators experience with a system and, to identify how well they cope with the technological system. A typical questionnaire consists of a limited number of questions, focused in the topic of interest, such as the operator opinion with design of the existing interfaces, operation problems, difficulty in the interaction, difficulty to perform tasks, physical interface properties, and monitoring problems.

The human factors checklists establish a review method to assure that the design has definitive and important criterions, establishing a comparison with the desired standards. They must indicate in clear and accurate way the information that is being looked for. The checklists do not consider the context in which the user activity is being carried out. They must be written in order to only provide two answers, yes or not.

Rating scales are composed of a question or statement that the user answers using a scale provided that usually offer a finite set of options. Users often find it much easier to provide ratings than to answer open-ended questions about the same topics. The time and effort involved in the evaluation is reduced.

The international standards for human-system interfaces (HSI) concentrate on the principles to be applied in order to design an interface which meets users and task need [6]. These standards can be used to specify details of the appearance and behavior of the user interfaces, providing detailed guidance on the design and criteria for the evaluation of user interfaces.

Some human factors guidelines are in terms of user interfaces features (provision of help, screen layout of a menu), and others state higher level attributes (consistency, flexibility). There are many industry standards and guidance documents for the HFE aspects of computer based HSI design [7], [8] and [9]. The use of human factors guidelines can result in human-system interfaces that are well-designed from the user perspective. In general, a well-designed human-system interface exhibits the following characteristics: accurately represents the plant; meets user expectations; supports situation awareness; supports crew task performance; balances workload; is compatible with cognitive and physical characteristics of the users; provides tolerance to error; provides simplicity; provides standardization and feedback.

Ethnographic study is a qualitative research method which aims to develop a thorough understanding of the current work practices of the users. The analysts visit users at their working environment and observe them as they carry out their tasks. However, observation alone does not tell the analysts why people behave the way they do. It is recommended to make interviews to let people themselves give an interpretation of their behavior. The analysts can then consider these interpretations and observe behaviors as they analyze the findings. The user activity is composed of tasks, which themselves are composed of actions, and actions are made up of operations. The activity is a coordinated, integrated set of tasks. The user activity analysis captures the richness and the complexity of the user activity, including the status of the operational procedures. The operators are systematically observed in their work environment [10]. The data collection is effected through field notes, photographs, simulator logs and audio-video recording system. The goal of this phase is to achieve a detailed understanding of the monitoring activities of the users, how they accomplish their tasks, enlightening the strategies of the users used to solve problems and how they interact and navigate within the interfaces [11].

Performance based tests involve asking users to perform scenarios, such as a plant startup, and measures of the users performance are obtained, such as time to complete a task, workload, and user opinions. This type of test requires a fairly controlled environment where the same scenarios can be repeated and used some type of simulation or engineering test facility, such as physical mockup, prototype, full-scope simulators and virtual reality technology.

The usability of a product can be defined as the ability of a product to be used with effectiveness, efficiency and satisfaction by specified users to achieve specified goals in particular environments. The user centered design methodology states that usability and the user experience should be considered at every phase in the life cycle of the equipment. The usability of a product is the attribute which contributes towards the quality of use and depends on the nature of the user, product, task and environment. The usability can be measured by the effectiveness, efficiency and satisfaction with which specified users achieve specified goals in particular environments.

The questionnaire for user interaction satisfaction is given to the users, after they carry out the tests. The questionnaire covers topics such as the user satisfaction with the interface design, operation, interaction, presentation of information, difficulty to perform tasks and physical interface properties. The users are asked to rate their opinions by means of a simple subjective rating scale reproduced for all questions. We use a modified Questionnaire for user Interaction Satisfaction (QUIS), a tool developed at the University of Maryland.

## 3. THE DIGITAL FLUOROMETER

The Fluorometer is an equipment used in chemical analysis laboratories, research institutes and nuclear fuel cycle companies. This equipment measures an unknown amount of uranium in ores, rivers, etc. The Fluorometer functioning is based on the uranium fluorescence when submitted to the ultraviolet radiation incidence. The fluorescence is measured by an electronic optic system with optics filters, photomultiplier tube, and a current amplifier. The control and the information processing of the equipment will be digital, with graphical interfaces for personal computer through which will be possible to carry out calibration, data storage and information readings. The block diagram of the equipment is shown in figure 1. It is formed by a photomultiplier tube with filters, a high voltage power supply to polarize the photomultiplier tube, a converter/amplifier current to voltage, a microcontroller, graphical display, a keyboard and a serial output (USB converter) to a personal computer.

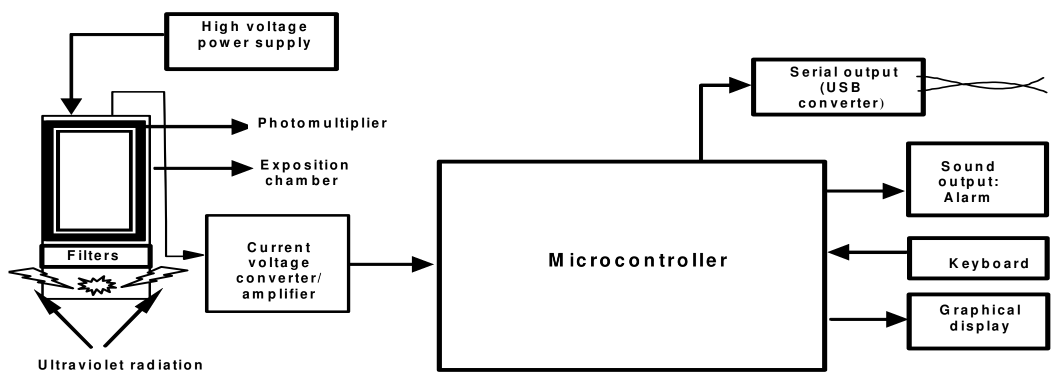


Figure 1. The Block Diagram of the Digital Fluorometer

## 4. THE METHODOLOGICAL FRAMEWORK

The standard ISO 13407 provides guidance on users centered design activities throughout the lifecycle of computer-based interactive systems [12]. The incorporation of this approach is characterized by the clear understanding and specification of the context of the use; by the specification of the user and organizational requirements; by the task requirements and by an appropriate allocation of the functions between users and technology. The process must start at the earliest stage of the project, when the initial concept for the system is being formulated, and must be repeated iteratively until the system meets the requirements. The requirements are recommended to be included in all phases of the lifecycle of the design, such as system scope definition, conceptual design, detailed design, implementation phase, tests phase and integrated evaluation. It is necessary a verification process in the first fourth phases and a validation process in the last two phases. Verification is an evaluation to verify that the HSI is designed to accommodate human capabilities and limitations as reflected in HFE guidelines. Validation is an evaluation using performance-based tests to determine whether an integrated equipment design (i.e., hardware, software, and personnel elements) meets performance requirements and acceptably supports safe and economical operation of the equipment. The figure 2 shows the lifecycle of the fluorometer design.

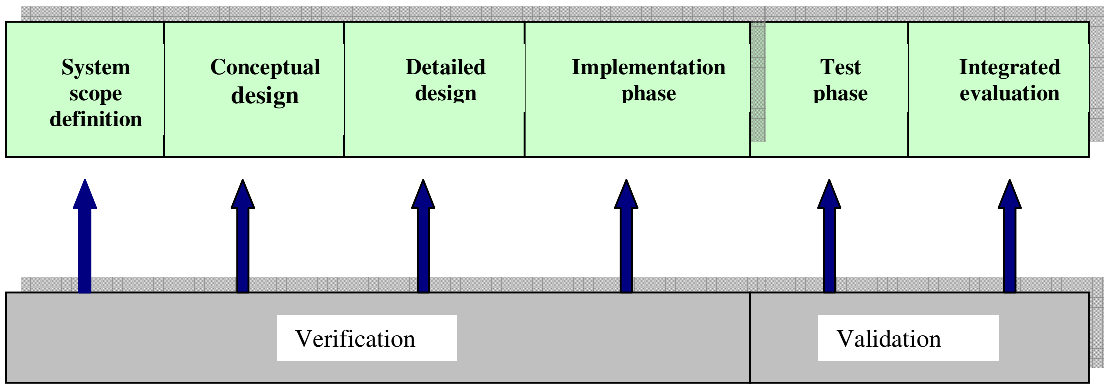


Figure 2. The Lifecycle of the Fluorometer Design

1. System scope definition: In this phase is important to define what kind of equipment will be built. It is necessary to describe what the equipment is intended to do, how it will be like, the analysis of the requirements specification, the restrictions of the equipment performance and the safety aspects. The equipment requirements are defined as the goals that the equipment should achieve and may reflect the user goals, too

2. Conceptual design: In this phase is done the functions analysis, the functions allocation, the task analysis, the analysis of the users, the analysis of the working environment and the analysis of the kind of the human-system interface that will be implemented. The objective of functions analysis is to specify the roles and responsibilities of the users in the performance of equipment functions and tasks. The functions allocation is the process of deciding whether functions should be automated, partially automated or specified as manual procedures. Task analysis is the analysis of functions that have been assigned to plant personnel in order to specify the requirements for successful task performance. The task descriptions provide information about the task, such as its purpose, its relationship to other tasks (performed in sequence or in parallel), time it takes, etc. The analysis of the users identifies the intended users and their characteristics (age, sex, occupation, past experience, working on the similar system). Through the analysis of the working environment is possible to identify which factors should affect the equipment functioning and the user work, such as noise, temperature, ventilation, humidity and illumination. The analysis of the kind of the human-system interfaces identifies which interfaces will be

designed based on the technological restrictions and on the available computational tools, such as ecological interface, manipulation direct and task-based.

3. Detailed design: The objective in this phase is to develop the hardware design, the logical design of the equipment, the mechanical design (connectors, mechanical box) and the human-system interfaces (HSI). This phase reflects the functional and physical design of the fluorometer. It meets users task requirements and details the general characteristics of a well-designed HSI.

4. Implementation phase: The logical structures designed in the previous phase are taken to a specific programming language. The human system interfaces (HIS) that give shape to the interaction design is built with the contribution of experts in graphic design. This phase is characterized by the integration between the hardware and mechanical design and the human system interfaces, converting the hardware and software design into the equipment functioning.

5. Test phase: In this phase tests are performed at laboratory with real users. The results will be useful to assess the fulfillment of the specifications defined in the requirements specification. Tests are performed to evaluate discrepancies between a design characteristic and a HSI guideline; toidentify design characteristics and features that will negatively impact users performance; to determine whether the impact is acceptable and to evaluate the performance with new HSIs.

6. Integrated evaluation: The equipment built is subject to validation tests to ensure that it complies with the requirements. It is a validation process. Validation is the process of determining the degree to which the human–interfaces system design and supporting mechanisms facilitate the achievement of operational goals of the equipment. It demands the users as participants, performing real tasks with the equipment in the work environment. The goal is to validate the integration of the design with the users actions, equipment response, human-system interfaces and procedures.

The figure 3 shows the methodology to include the issues of the users and their activities in the development of the new digital fluorometer. The level 1 concerns to the phases of the lifecycle of the digital fluorometer. The level 2 concerns to the methods used to guarantee the involvement of the users and the allocation of their requirements in each phase of the design process.

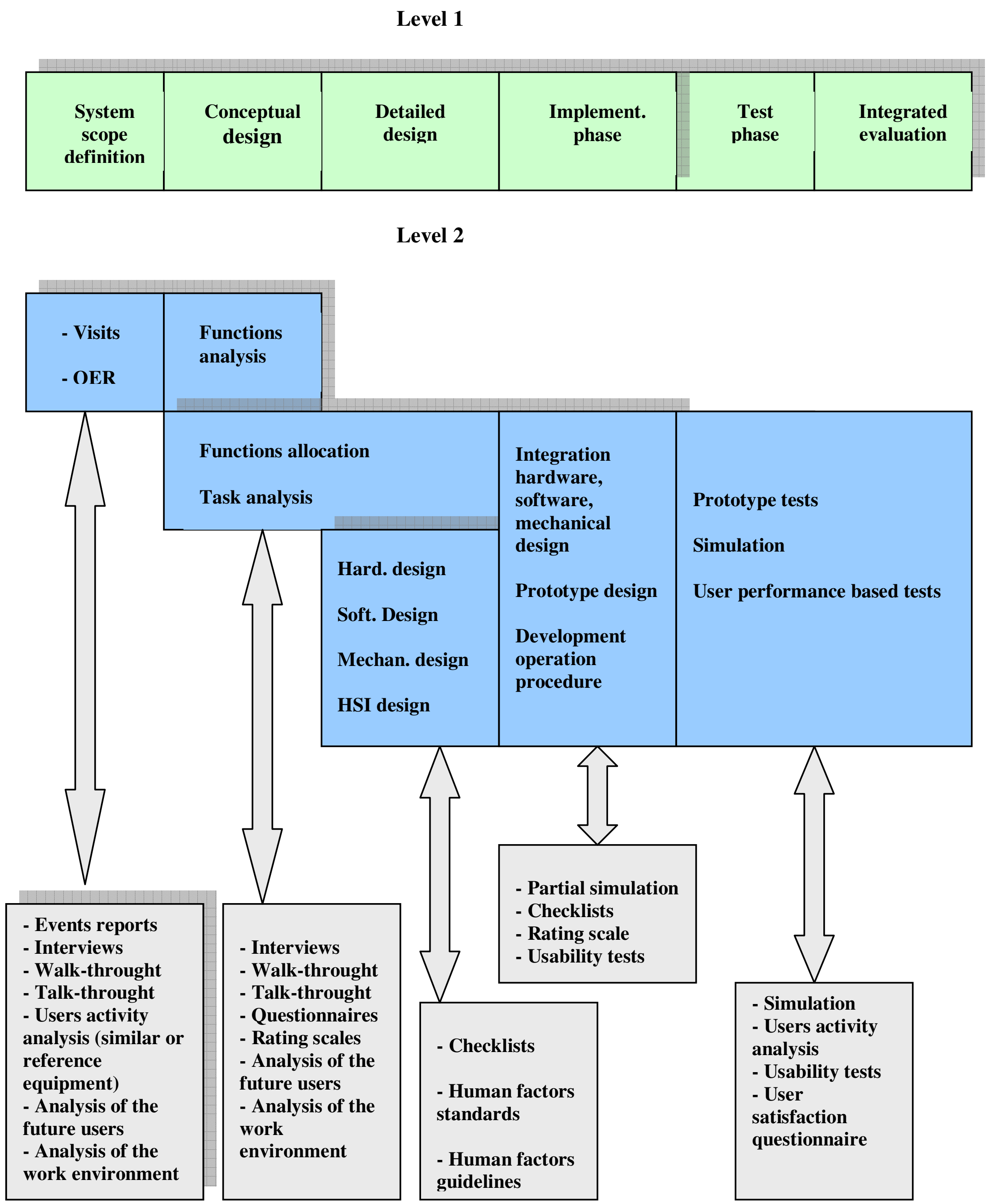


Figure 3. The Methodological Framework

## 5. CONCLUSIONS

The proposed methodology framework, shown in figure 3, emphasize the use of a detailed number of techniques and methods to guarantee the inclusion of the end-users in the development process of the new digital fluorometer. From the systemic point of view, all analyses have to be performed taking into account the functional requirement*s* of the fluorometer under development. These requirements, defined and established in the early phases of the design process, represent the basis for the development of a structural model of the equipment; represent the functional model of the equipment with the specific goals and functions required for different subsystems and components and represent the contextual model with a useful description of the context and working environment, in order to identify the factors that can affect human performance. A wide range of methods and techniques can be used to carry out these activities, such as:

- system scope definition: analysis of the similar equipments, interviews, users activity analysis performing tasks with similar equipment, analysis of the future users, analysis of the work environment, talk-through and walk-through;
- conceptual design: interviews, talk-through, walk-through, questionnaires and rating scales;
- detailed design: checklists, human factors standards and human factors guidelines;
- implementation phase: partial simulation, checklists, rating scale and usability tests;
- tests phase and integrated evaluation: simulation, users activity analysis performing tasks with the new equipment, usability tests and user satisfaction questionnaire.

Over the last decade, there has been an increasing interest in addressing the requirements of the users during equipment development, to enhance safety, to reduce human error and to incorporate aspects of usability such as comfort, effectiveness, ease of use, learning, training, maintainability and servicing. Additional factors must be considered during equipment design to ensure a good fit with user requirements, such as the design of work system. The equipments design must fit into the working and living patterns of the users to allow them to be used efficiently and effectively.

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