DEVELOPING A HUMAN FACTORS TOOLKIT TO COPE WITH THE MULTI-PROJECT SITUATION

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ABSTRACT

Beside of the challenge from technology improvement and stricter safety review in the area of human factors engineering and integrated human system interface resources design, the pressure from the engineering efficiency and quality continues increasing nowadays while "one-design-several-sites" is becoming more and more common for the nuclear energy industrial in China. A toolkit based on relational database technology was developed to support the whole process of HFE analysis for designer. A through requirement analysis was conducted. Beside of requirements form technical view of point, the considerations from engineering process, quality management, computer technology and data interface were also involved as a whole. During the implementation, resolutions were developed to solve problems like multi-project, multi-group and so on. Lessons learned during the design and development process are summarized as references for similar projects.

Key Words: HFE, Software Tool, Multi-project

1 INTRODUCTION

Human factors engineering (HFE) has already become a necessary and essential element in the design process of nuclear power plant, and the scope and depth of HFE is increasing with the development of technology and review requirements. The implementation of HFE in the nuclear energy industry in China could be divided into three stages [1], and the tools to support the design of HFE have also evolved during these three stages in author's organization:

- Stage 1: Before 1992, no chapter 18 time

There was no chapter 18 in the safety analysis report of 300 MWe Qinshan NPP, which is the first self-reliance NPP in China and was put into operation in December 1991. Only limited HFE information like anthropometry and control room ambient condition was covered by chapter 7, and only paper-pencil tools were used in that time.

- Stage 2: 1992~2008, Preliminary HFE application time

In this period, several plants were designed by different countries like China, France, Canada and Russia and were constructed in China, and chapter 18 was involved formally. Microsoft Office suite and AutoCAD from Autodesk were the key software which supports the HFE design process. To manage the simple calculation (e.g. anthropometry, task analysis) and the data generated during design, Microsoft Excel was widely adopted. And in one exported project, Microsoft Access was used for design verification and problem tracking for the first time.

- Stage 3: After 2009, systematic HFE application time

For the past several years, the third generation NPPs became the main technology direction in China and NUREG-0711[2] has been used as the main reference during the safety review in China. Although the unification of reactor type and technology is still in debate, unlike the "one-design-one-site" situation in the second stage, "one-design-several-sites" is becoming more and more common. With the development of HFE and IT technology, more and more business or self-developed software tools are put into use.

This paper will introduce the considerations and implementation of the toolkit which was developed during past years by the author's organization to cope with the emerging requirements from HFE design. From the perspective of the big picture, the whole collection of HFE software "H-Lab" is classified by three categories as illustrated in Figure 1:

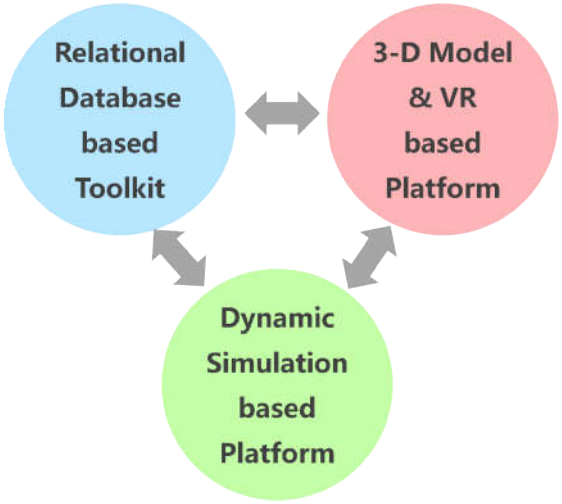

Figure 1. Overview of HFE Software Collection H-Lab

The relational database based toolkit which plays the leading role in the engineering process will be discussed in this paper. The 3-D model and virtual reality (VR) based platform is mainly used for dimension-related design in main control room and HFE verification activity for the local area. The dynamic simulation based platform is focused on the dynamic nature of human system interface (HSI) resources and support the engineering test and preliminary integrated system validation. The data is communicated among these three parts. Although the detailed description of the second and third platforms of H-Lab is beyond the scope of this paper, the interfaces with the relational database based toolkit will be clarified.

2 REQUIREMENT ANALYSIS

During the last decade, the digitalization of the nuclear design has been advanced rapidly. In author's organization, the design management system (DMS) was established and functions well to achieve the document level design management for the whole organization. At the meantime, the data level design management is formed but is managed separately by different design groups or departments. The organizational level data center is still under integration and development. In author's organization, the digitalization of HFE design process was put on the agenda in 2010.

As stated in the previous chapter, an ACCESS database was used for an export project 10 years before. The limitation of that "easy use" tool was emerged during that project, so that a more professional and systematic toolkit was required. During the development of DMS, the HFE group also integrated the activity of operating experience review (OER) into the Experience Feedback Platform. However, the attempt was not a success because of the information overload and the tediously process, while the

platform should satisfy the needs of all the design groups and management requirements. Furthermore, due to the complex of NUREG-0711, it was very hard to find a business toolkit to support the whole design process of HFE and to satisfy the project specified features. As a result, it was decided to design a software named "H-Lab" which is realized with the help of professional software company.

A through requirements analysis for H-Lab was implemented at the beginning to make sure the right thing would be done. Beside of requirements form technical view of point, the considerations from engineering process, quality management, computer technology and data interface will be addressed during following sections in detail.

2.1 Requirement from HFE Elements & Activities

Based on NUREG 0711, there are 12 elements classified into four stages (from planning and analysis, design, verification and validation to implementation and operation) in the HFE program as illustrated in figure 2:

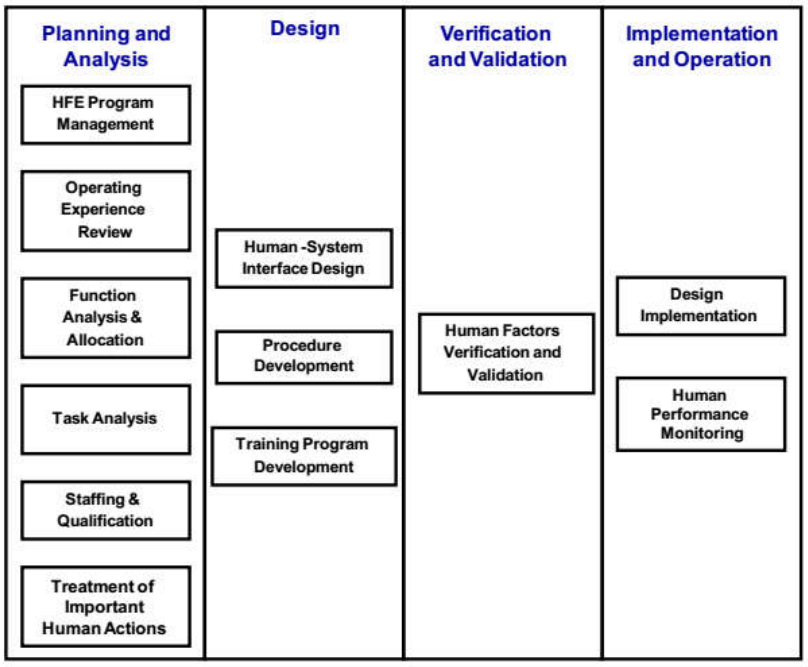

Figure 2. Elements of the HFE Program's Review Model

Because it is decided to use rational database technology, the most common and widely applied data organization structure, the top criterion would be the data size and structure of certain HFE activity. The other practical criterion is the allocation of responsibility, while not all the HFE activities are in charged by the HFE group of designer. The analysis of requirements is as below:

1) HFE Program Management

From the perspective from database, HFE Program Management is a simply one. The project background information and users' authority should be managed for this element. And above requirements could be easily integrated into the basic database management functions. Secondly, the HFE issue tracking system, which is the mandatory criteria from NUREG-0711, should be covered by this element.

2) Operating Experience Review (OER)

In the OER, hundreds of experiences from different sources are collected and analyzed by more than ten different design groups. This is a typical situation which could be improved by the rational database technology. But questions like shall we define these experiences as demands/inputs or problems, shall we treat OER as a single module or integrate it into problem tracking or HED Solving module should be answered before developing. Generally, most issues from the standards like NUREG/CR-6400[3] and NUREG-0933[4] are very high level so that the satisfaction condition is easily assessed during the preliminary design stage and could be closed during the OER. However, issues from operator interviews or incident reports are more detail and HSI resources related which are very hard to generate the solution and would kept open at the end of OER. Finally, we decided to treat issues from OER as problem in this toolkit, and the design group of certain OER issue could make their own decision flexibly.

During the OER, on-line questionnaire web services are surveyed and discussed, however, the servers for this kind of web service are generally hosted outside, which cannot meet the data protection policy. So that a Microsoft word template with VBA is used to facilitate the preliminary survey before the face-to-face operator interviews.

3) Function Requirement Analysis and Allocation (FRA&FA)

Considering the data amount and the tree structure, it is decided that the data from FRA&FA would not be included in HFE toolkit. Microsoft Word is still used to document the results of analysis.

4) Task Analysis (TA)

The TA is composed by two different activities named function-based task analysis (FBTA) and operational sequence analysis (OSA). FBTA is the follow-up activity of FRA&FA, and decomposes functions into the displays, controls and alarms level. Whether to cover FBTA or not is also in debate in the first. Unlike FRA&FA, which is conducted by limited number of experts, FRA&FA requires the involvements of many process experts from nuclear and common islands. Furthermore, the data mount of FBTA increases dramatically compared to FRA&FA, and statistical analysis is also preferred to support the integration and summarize analysis. There is no hesitating to cover OSA in the toolkit. The challenge is that all the methods adopted in OSA should be described in relational structure. The flexibility for potential modification of existing methods should be deliberately designed in advance, and the graphical presentation style of results should be simplified or abandoned.

5) Treatment of Important Human Actions

This element is conducted by the probability safety analysis (PSA) group in the author's organization, and only the integration of the important human actions into HFE program is within the scope of HFE project. Therefore, the digital tool for this element would be covered by the PSA group but not HFE group's software.

6) HSI Design

There are several HFE activities in the HSI Design, like HFE review, HSI design guidelines, and HFE engineering test. HFE review includes the review of high level HSI design documents by HFE group, and cross-discipline review meetings with the participation of HFE experts. Issues identified in HFE review would be put into the HFE issue tracking system. HSI design guidelines, which are the core activity of HFE, include two stages, which are generating the guidelines and the establishing of track links between guidelines and HSI design documents. This is a typical demands analysis problem which is very suitable for database technology. The purpose of HFE engineering test is to provide inputs to the design of HSI resources which cannot be covered by HSI design guidelines. The goal-oriented feature of engineering means that the methodology would not be limited in performance-based tests. The process of HFE engineering test would be covered by the dynamic simulation platform in H-Lab. But issues identified in engineering test would be considered by the HFE issue tracking system together.

7) HF Verification and Validation (V&V) & Design Implementation (DI)

V&V is the most time consuming element in the design stage. The V&V element consists of four major activities: HFE Design Verification (HDV), HSI Task Support Verification (HTSV), Integrated System Validation (ISV, including sampling of operational conditions), and Human Engineering Discrepancy (HED) Resolution:

- HDV activity integrates the information of HSI design guidelines and HSI resources, and generates a huge number of data. The high workload of HDV also requires a group of HFE experts to work together during the HSI design process. A single module should be developed to manage the process of HDV.
- The main part of HTSV is the final check of the results of TA based on updated information. At the same time, new forms in the database should also be considered to manage the verification data from minimal inventory and other specified technical analysis.
- ISV, which is a performance-based activity like HFE engineering test, would be covered by the dynamic simulation platform in H-Lab as well.
- There is no doubt that the process of HED resolution should be digitalized. The challenge is how to define the relationship among HFE issue tracking system in HFE program management element, issues from OER, HED identified during V&V and design implementation, and issues identified throughout the life cycle of the HFE aspects like TA. To make the system simple and flexible, a separate "HED & Problem Tracking Module" was planned to cover all above issues.

Although DI is a separate element, the methodology is same as HDV. Therefore, it would be more convenient to use the function of HDV directly to cover DI.

8) Operation Oriented Elements

Four operation oriented elements including staffing & qualification (S&Q), Procedure Development, Training Program Development and Human Performance Monitoring (HPM) are dismissed from the scope of the rational database based toolkit of H-Lab while they are not within the responsibility of designer.

2.2 Requirement from Engineering

2.2.1 The Update of Single Project

The design of a nuclear power plant lasts several years, and the duration is much longer for new design than reproduced design. And due to the complex of nuclear power plant, the design continues updating from the preliminary design to detail design. This continued improvement process means that the reversion or the baseline management should be systematic solved during the design and development of the toolkit. The real challenge of project updating is how to define the level of reversion management to balance the cost and complexity.

2.2.2 The Coordination of Multi-project

Nowadays, "one-design-several-sites" is becoming more and more common in China. After the construction of the standard project, there would be several follow-up projects which will be constructed based on the standard one with only tiny modification. The manpower shortage becomes one of the highest problems for the designer. So the design relationship between standard project and the follow-up projects is carefully divided into three kinds:

- Common Design, which is total same in the standard project and the follow-up project.
- Modified Design, which means only tiny modifications are made in the follow-up project. For example, the background noise in the standard design is 55 dB(A), but the follow-up project makes the criteria stricter to 50 dB(A).

- Unique Design, which is used for the features are totally different in the follow-up project. For example, the follow-up project adds the criterion for the echo in the control room, but the standard project has no requirement in this feature.

Therefore, to reduce the manpower consuming, a very basic requirement of the toolkit is that it should be able to record these kind of information and support the data reuse. Besides the clarification of the relationship of the design feature between standard and follow-up design, the other challenge is how to define the level of managed feature.

2.2.3 Parallel Design of Multi-group

Most of the activities in HFE program cannot be implemented by an individual engineer. Moreover, the coordination mode of engineers is not linear but parallel. The toolkit shall take this requirement not only into the technology selection, but also the data structure design.

2.3 Requirement from Quality Management

Nuclear industry is very different from other industry from the quality control to insure the safety of the nuclear power plant. In author's organization, every document shall be controlled in three or four checking steps, which are compiling, review, approve and authorization. The process of DMS is also based on this requirement. However, business software and most of the self-developed software don't consider this process. Lessons learned is if the design data and checking data are not included in same software tools, the long-term usage preference will be damaged especially due to the extra workload for compiler to synchronize data from other designers. Another mandatory requirement from quality management is that the records of updated points should be listed in detail. The "track changes" function is very helpful to record the updates if Microsoft Word is used. If a software tool asks the user to manually compare and record the differences, the probability of mistakes will increase and the long-term usage preference will also be affected.

2.4 Requirement from Data Interfaces

The systematic consideration on data interfaces is another vital factor influencing the success operation of digital design tools. Data interfaces could be divided into three types:

- Data interfaces within the relational data base based toolkit of H-Lab, like the data flow from OSA to HTSV.
- Data interfaces within H-Lab, like the HEDs from the dynamic simulation based platform to relational data base based toolkit.
- Data interfaces outside H-Lab, for example DMS (e.g. the information of engineers), I&C design platform (e.g. the information of displays, controls and alarms).

The HFE software should have the ability to keep relatively independent, and at the same time, be able to be connected to the highway of data center in the future.

2.5 Requirement from Computer Technology

Several demands were listed from the perspective of computer technology like:

- Browse/Service (B/S) architecture should be used to increase the adaptation of toolkit and reduce the maintenance workload of users;
- Maximal concurrent access number should be greater than 30;
- Data could be exported in Microsoft excel or word format;
- Backup of data should be triggered every day if there is any change of the data.

3 IMPLEMENTATION

Based on the through requirement analysis addressed in chapter two, the functions are grouped into five modules as described in table 1 and the development was implemented phase by phase from 2012 to 2016:

- Phase one: Toolkit Management Module, Task Analysis Module
- Phase two: HSI Design Guidelines Module, HDV/HTSV Module
- Phase three: HED & Problem Tracking Module

Moreover, DIIV Module for 3-D Model & VR based platform is already put into use but the HF Test Module for dynamic simulation based platform is still under development.

Table I. Structure & Modules of H-Lab

No.	Element/ Activities	Relational Database based Toolkit	3-D Model & VR based Platform	Dynamic Simulation based Platform
1	HFE Program Management	[0]Toolkit Management [4]HED & Problem Tracking Module		
2	OER	[4]HED & Problem Tracking Module [*]DMS Experience Feedback Platform[Note1]		
3	FRA&FA			
4	TA	[1]Task Analysis Module		
5	S&Q			
6	Treatment of IHA[Note2]			
7	HSI Design	[2]HSI Design Guidelines Module [4]HED & Problem Tracking Module	[5] DIIV Module	[6] HF Test Module
8	Procedure Development			
9	Training Program Development			
10.1	HDV	[3]HDV Module	[5] DIIV Module	
10.2	HTSV	[3]HTSV Module	[5] DIIV Module	
10.3	ISV			[6] HF Test Module
10.4	HED Resolution	[4]HED & Problem Tracking Module		
11	Design Implementation	[3]HDV Module		
12	HPM			
Note1: Company level platform, not HFE specified; Note2: Managed by the PSA group, not the HFE group.				

In the development of this toolkit, solutions were raised to cope with the requirements, for example:

- The configuration management is set in a very detailed level compared with traditional file level control. For example, reversion number is allocated for individual HSI guideline, verification item, HED or problem.
- The reversion control is distinguished into literature change and technical change, and only technical change will activate the updating process for follow-up analysis.
- New attributes are arranged for follow-up projects to describe the relationship among standard design, old version of follow-up design and new version of follow-up design. For the follow-up project, the first step in the analysis is to classify the relationship, and the real analysis activity is conducted in the second step to deal with modified and unique design features.
- A discussion log function is embedded to support the compiling, review, approve and authorization process, and the authority of modification during design is only allocated on the compiler to reduce traceability burden of toolkit. The accumulation of discussion logs provides an effective way to achieve knowledge management as well.
- A lot of queries are designed to support the summary of raw data. For example, the list of differences in document updating could be easily automated exported in most situations.
- Besides excel format, word format export is also supported in some situations to improve the automation level. And to connect the H-lab and DMS, the relationship of items in H-Lab and documents in DMS could also be managed.

4 CONCLUSIONS

The toolkit which is a part of the whole HFE software introduced in this paper has been put into use and operates well. Not only the efficiency is increased, but the design quality is also improved. Based on the feedbacks, there is no need of improvements for this toolkit in three to five years. While it is the first time for the author's organization to develop this kind of toolkit, some lessons learned in the process are as follows:

- Beside of translating the methodology and technical considerations into the software toolkit, considerations from non technical parts are also vital to the success.
- To ensure the well operation of the system in a long time, plan and design from a higher level and in a dynamic network perspective would be very helpful. Data uniqueness and interface standard are the core requirements, while it is impossible to solve the problem by single software toolkit. The balance of self-developed and business software is also a challenge.
- Users don't know what they want exactly until they use the final product. The communication of demands with software developer was harder than supposed. Increasing the frequency of face-to-face meeting and feedbacks are necessary. If there is a rapid interface modeling tool (e.g. Axure RP) available in your organization, don't hesitate to use it.
- When the complexity of the process or data increases in one place, don't forget to consider the simplifying or flexibility in other place.

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