A STRUCTURED DATA MODEL FRAME FOR HUMAN FACTORS APPLICATION

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ABSTRACT

Building a Human Factors analysis and Verification & Validation case for new control rooms and even for control room modifications is a highly labor intensive project. Any optimization that can be made in the process translates into savings in the overall control room project schedule and budget. Several support tools from word, to excel, mind maps and databases have been traditionally used by human factors practitioners to conduct the analysis and document its results. While the use of these tools has had satisfactory results, they don't provide in our experience strong enough means for configuration control management, to avoid duplicities, streamline the analysis processes and allow collaborative team efforts.

This paper documents how the established practices (methods, processes and tools) were questioned, which were the sources for comparison and how the results were translated into requirements for the new tool constituting the data frame model for Human Factors Engineering applications. The exercise has allowed us to evaluate the efficiency of our current practices in comparison to previous ones while improving our compliance with the quality assurance standards.

Key Words: Human Factors Engineering, analysis tools, Verification and Validation tools, Human Machine Interface.

1. INTRODUCTION

Tecnatom has been involved in Human Factors Engineering and Control Design activities since the mid-eighties. Starting in the field with Detailed Control Room Design Reviews for the Nuclear Power Plants (NPPs) in Spain, the company got involved early on with the Human Factor (HF) programs for the Advanced Light Water Reactors (ALWR). Since 2009 we have supported the nuclear program in China delivering eight control rooms and assisting Chinese companies in the analysis, design and construction of at least six more. All along the HF team has supported the existing fleet in Spain in their control room modernization projects and is currently working with the personnel of Krško NPP in the design and construction of their Emergency Control Board [1].

To execute this wide variety of projects the HF team had developed several methodologies and used a wide variety of in-house and commercial tools. In 2014, during the final stages of the delivery of the first two control rooms in China and immersed in several control rooms modification projects, a panel of experts was involved in a benchmarking project to assess our methodologies, processes and tools for the execution of HF programs. The paper "New Environment for Human Factors Engineering Analysis, Design and Test" [2] documented the early requirements, lessons learned and principles that will guide the improvement process on HFE practices.

The sections below document the benchmarking sources, methods and the demonstration of the reviewed tools.

2. BENCHMARKING SOURCES AND RESULTS

The methodologies, processes and tools being used in any HFE and control room design activity were reviewed by the benchmarking team against many kinds of reference sources that included, standards, guidelines, papers, internal procedures successfully applied in related activities and third party tools. The following sections discuss the material being used by the HFE Team at Tecnatom, the external (other Tecnatom areas were treated as external references) and the outcome or actions associated to the review.

2.1. Sources identification

The identification of the sources to compare was made by the review of the attendance reports to conferences, the participation on international panels of experts on the HFE related matters and the technology surveillance activities that are carried out as part of the continuous improvement programs of the Tecnatom organizations.

Table I: Sources and benchmark activities

Item	Internal Source Description	External Source – activity performed
1	Project specific HFE programs	NUREG-0711 [4] and IEC-60964 [6] – Compliance review for future projects
2	Operating Experience (OE) Review Methodology	NUREG-0711 [4] and the practices applied by Tecnatom's OE organization (provides service to Spanish NPPs on any OE, collected from INPO, WANO and other sources) were reviewed to update the process
3	Treatment of Important Human Actions Methodology - pending	NUREG-0800 [3] & Nureg-0711 [4] – Methodology definition
4	Methodologies for the analysis of functions and task analysis	NUREG-0711 [4] – Compliance review
5	Methodologies for the allocation of functions	NUREG/CR-3331 [5] – Methodology redefinition
6	Human System Interface Design Methodologies	Tecnatom's simulation group configuration control procedures, practices and tools
7	Verification and Validation Methodologies	Tecnatom's conclusions on the discussions held during the 2015 NEA workshop on control room validation. Evaluation of SACADA1 as a tool for supporting HFE validations.
8	HFE Tools	Several sources [8], [9] and internet searches. Experiences of the use of tools for Tecnatom Simulators interfaces design TeamSketch ©

The revision 3 of NUREG-0711 [4] prompted several changes in our methodologies and processes. Although at the time of the review there were no HFE projects using the revision 3 as reference, the

[1] SACADA is an NRC & INL tool designed to support collection and analysis of simulator data for Human Reliability analysis applications

benchmark activities, allowed us to assess the differences with revision 2, prepare new methodologies and be ready before the kick-off of Krško project[2]. The benchmark also identified a need to better substantiate the allocation of functions that was done by using the guidance on NUREG/CR-3331 [5].

2.2. Processes optimization activities

The benchmark team also identified the need for an optimization of the processes involved in the execution of an HFE program. Two main actions were taken to do so:

1. The application of a graded approach for Task Analysis, that focuses with greater detail on those tasks involved in the maintenance of the plant safety or in a non-planned plant safe shutdown. The approach is hierarchical starting with system tasks to progress using operating sequences into plant level analysis. This analysis mirrors the hierarchical structure established during the functional analysis.

2. The development of a tool that provides a structured data model frame for the application of the methodologies. The details of this tool and how it helped to optimize the HFE program activities will be examined on the next sections.

2.3. HFE tools benchmark

Tecnatom HFE team had several in-house developed tools that had been extensively used in the last few years for the application of human factors programs. This in-house tools covered different elements of the HFE Programs and had in some cases, some performance or design gaps that wanted to be corrected. The in-house tools review summary is included in the Table II:

Table II: review of Tecnatom in-house tools for HFE program support

ELEMENT SUPPORTED	DESCRIPTION	STRENGTHS, GAPS & DEFICIENCIES
HFE Analysis	Access databases that supported the Functional Requirements Analysis, Allocation of Functions, Task Analysis and part of the Human System Interface (HSI) Design. The data populated in them was used to automatically generate reports (word and pdf) that documented the results	[S] – Suited work methodologies, well known by HFE team, HFE analysis data was used for HSI definition ensuring consistency. [G] – modifications were needed to address new methodologies requirements (2.2) [D] – designed for plant system analyses, did not support well a hierarchical structure. Databases also had some performance issues while generating long reports.

[2] Krško uses NUREG-0711 Revision 3 as reference

ELEMENT SUPPORTED	DESCRIPTION	STRENGTHS, GAPS & DEFICIENCIES
MAESTRO	Access database that read the HSI design data from the HFE analysis databases (for all plant systems) creating configurations based on input baselines	[S] – improved consistency and quality for HSI reviews. [G] – did not covered the HFE analyses. [D] – none identified
Sherlock and Moriarty	Software queries designed to look for inconsistencies between the implemented design and MAESTRO data	[S] – improved dataset integration during the implementation of the operating displays in the control rooms. [G] – data origin/software specific, concept is valid but tool needs to be rebuilt to suit each project [D] – none identified
SICOTASK	Collection of software queries on HFE analysis databases to identify Task Support Verification (TSV) activities	[S] – reduced the time spent by the verification team on low value added discrepancies identification [G] – needed to be expanded to include other aspects of TSV [D] – had some performance issues.
VALS & SAMVA	Tools built to assist the verification and validation activities, facilitated the review of interfaces, alarms and procedures, maintaining traceability of comments from the end users.	[S] – very useful on talk-through / walk-through validations [G] – inputs configuration control was a manual process [D] – none identified

The tool predominantly used for HSI design (specially software displays) was Microsoft Visio. The main issue the main issue the design team found was the lack of connection between the HFE analysis tools and the Visio diagrams, that made maintaining the consistency between them a burden for the team.

In addition to the review of the internal tools a 2009 Brookhaven National Laboratory document [8], the Proceedings of the NPIC&HMIT 2015 [10] and internet queries, facilitated the identification of external tools. The goal of this part of the research was to identify make them known to the HFE projects managers and evaluate them against our tools Out of the total 100 tools identified, 24 of them were found relevant enough to go through a more in depth review, these tools are listed on Table III: External HFE tools reviewedTable III.

For each relevant tool the team developed a datasheet with practical information, like the owner/designer, if it was a commercial tool, an evaluation of its usefulness or interesting features and its price. Everything is compiled in a report that is being kept updated whenever a new tool is identified or more information is found about one already identified.

Table III: External HFE tools reviewed

HFE PROGRAM ELEMENT	TOOL
Task Analysis	• FRAFATA assistant • Micro Saint Sharp (P) • TaskArchitect (P) • Vision
Human Reliability Analysis	• IPME • MIDAS • SACADA
Workload Analysis	• TAWL • ECAT
HMI Design	• CSDT • SAMMIED CAD • SketchUP / SketchUp Pro
Verification	• CREATE • ErgoMaster • HFE-AT • Jack • ManneQuinBE
Validation	• Morae (P) • MVTA • Smart-Its • TacWISE • The Observer XT (P) • VE Training • Virtual Reality Technology

3. A TOOL FOR PROCESSES OPTIMIZATION

During the execution of the projects mentioned in the introduction Tecnatom HFE team became more aware of the increasing pressure to optimize the project execution. The HFE activities and the HSI design for new NPPs and Control Room modernizations, are intimately intertwined with other activities.

The plant or plant modification design is typically being produced, providing input to both the HFE activities and the development of simulators (engineering or full scope ones). Being the full scope simulator the ideal platform to evaluate the design, the HFE team must (for schedule constrains) have other tools and methods (mock-ups, walk-throughs, talk-throughs) to do so. Also, the capability of incorporating the plant design changes in an efficient manner becomes critical when the HFE team wants to be able to inform the HSI and plant design, make modifications in it based on the analyses and evaluations and test the results.

Activities like procedure development and the Systematic Approach to Training (SAT) also rely on the HFE analyses (the task analysis) as input. The ability to provide prompt input to those activities and to track the changes due to plant design modifications, provides significant advantages on the cost and quality of the materials (training and procedures) produced.

It is also worth to mention, the current situation of the power generation industry that it is having important effects in the viability of new nuclear projects or plant modifications. In this scenario of budget restrictions HFE projects need to be (sometimes more than others disciplines) more cost efficient, increasing its added value.

These were the driving factors for developing a suite of tools that optimized the HFE program activities as much as possible and

4. THE TOOL AS A DATA MODEL

The benefits of having a tool built as a structured data model frame to conduct the activities of a Human Factors Engineering (HFE) program are discussed in this section.

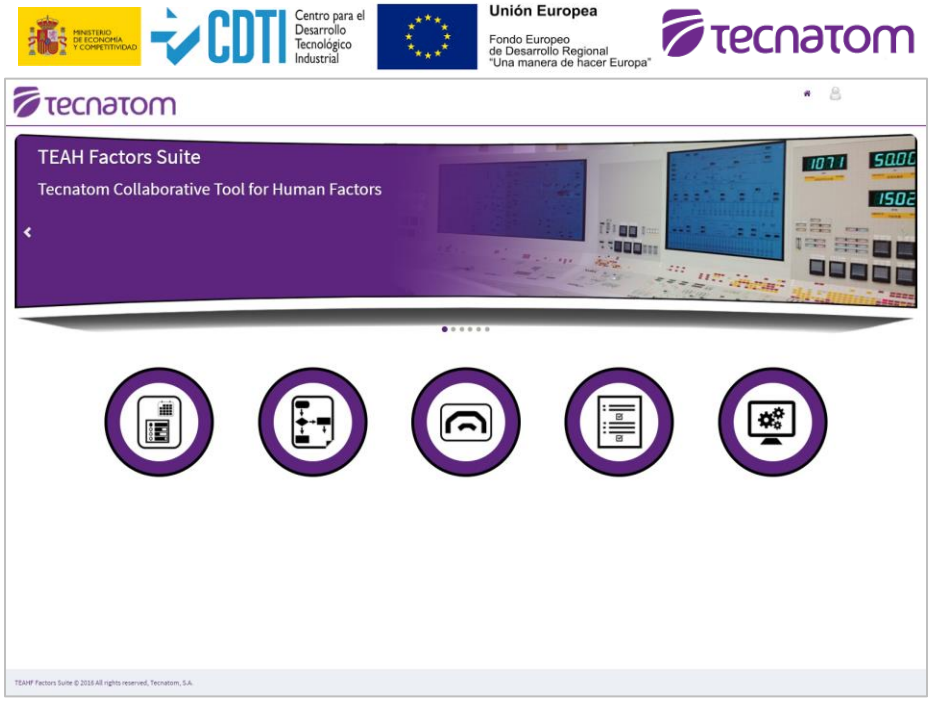

Figure 1: Access page to TEAH Factors Suite

The tool design concept is to build a tool that integrated the forms and data information to perform:

- Human Factors Engineering analyses activities, Human System Interface design and Verification and Validations of both
- The tools should support the design control processes and the project management (including HFE Issues tracking tool)

TEAH FACTORS (Tecnatom Application for Human Factors) SUITE contents a set of tools that support the execution of a Human Factors Engineering program, and specifically the following activities of it:

- Project Management
- HFE Analysis

- Design of Human-System Interfaces (HSI)
- Verification and Validation (V&V)
- Alarms and Procedures definition

To meet the design principles the solution adopted was a web based tool with an SQL Server database for data storage, that benefits from communication with SharePoint for documentation and project management activities and the Tecnatom' simulators interface design tool TeamSketch.

The three different software environments and the shared data are represented in the Figure 2.

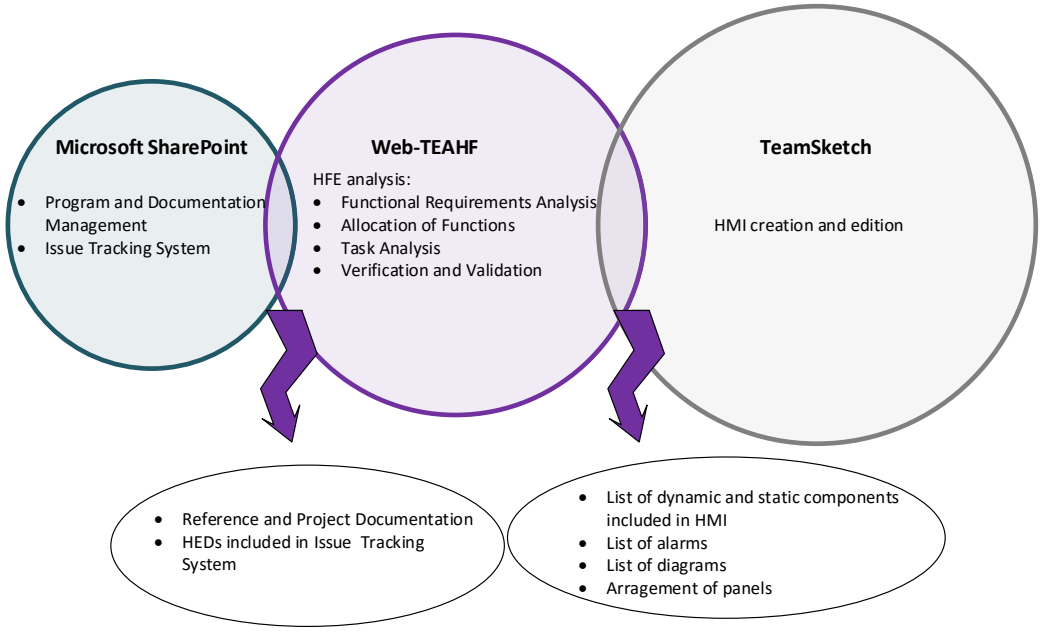

Figure 2: Software environment and information flow on TEAH FACTORS

4.1. Program and documentation management

The HFE program management activities including documentation control and Human Factors Issues resolution and work packages allocation are supported in specific Microsoft SharePoint site customized specifically to fit the requirements of this kind of projects.

It was identified by the panel of experts participating in the benchmark activities that this was an area that could significantly impact the overall project performance. The early tests performed point to a 70% reduction on the hours dedicated to design control, since the reference documentation used for the analysis and design is linked with the analysis forms in the tool and the SharePoint documentation management capabilities allow for better baselines control than other methods.

4.2. Analysis and design modules

These modules contain:

1. **HFE Analysis** – All the forms required to perform a Functional Requirement Analysis, Allocation of Functions and Tasks Analysis in accordance with the HFE program defined in NUREG-0711 Revisions 2 and 3 in accordance to Tecnatom methodologies. The Figure 3 shows the interactive flow chart that guid es the analyst to execute the allocation of functions.

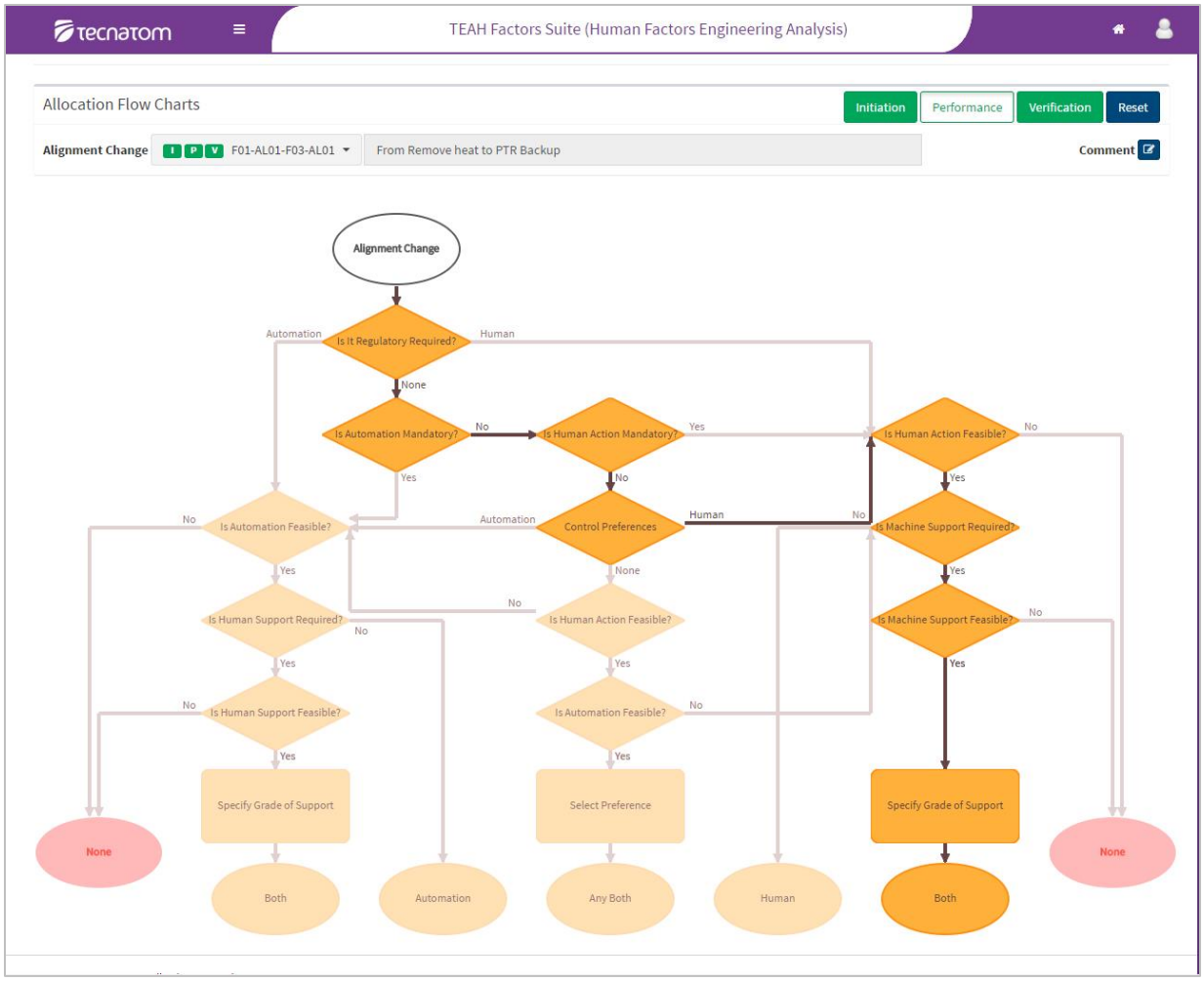

Figure 3: Example of allocation of functions flowchart

2. **HSI Design** – The lists of alarms, operation displays and panel interfaces. The style guide elements for displays and panels design are also managed here. Guides to develop Operating Procedures based on task analysis and the alarms prioritization definition is also carried out in this module, in accordance to the Alarm Processing and Diagnostic System (APDS) methodology developed by Tecnatom.

4.3. Verification and Validation module

This module supports the design verification of the interfaces and allows to reuse previous verifications experiences to guide the evaluation team. Validation support tools to collect comments in context with the interfaces during partial validations are also accessed from this module.

The module has the complete set of guidelines from NUREG-0700 [7] loaded in it. The designers and reviewers are provided with a detailed view of the guidelines fulfilment for each interface evaluation. Human Engineering Discrepancies are originated in this module and managed on the SharePoint for their resolution, tracking the comments from evaluators and designers as shown on Figure 4

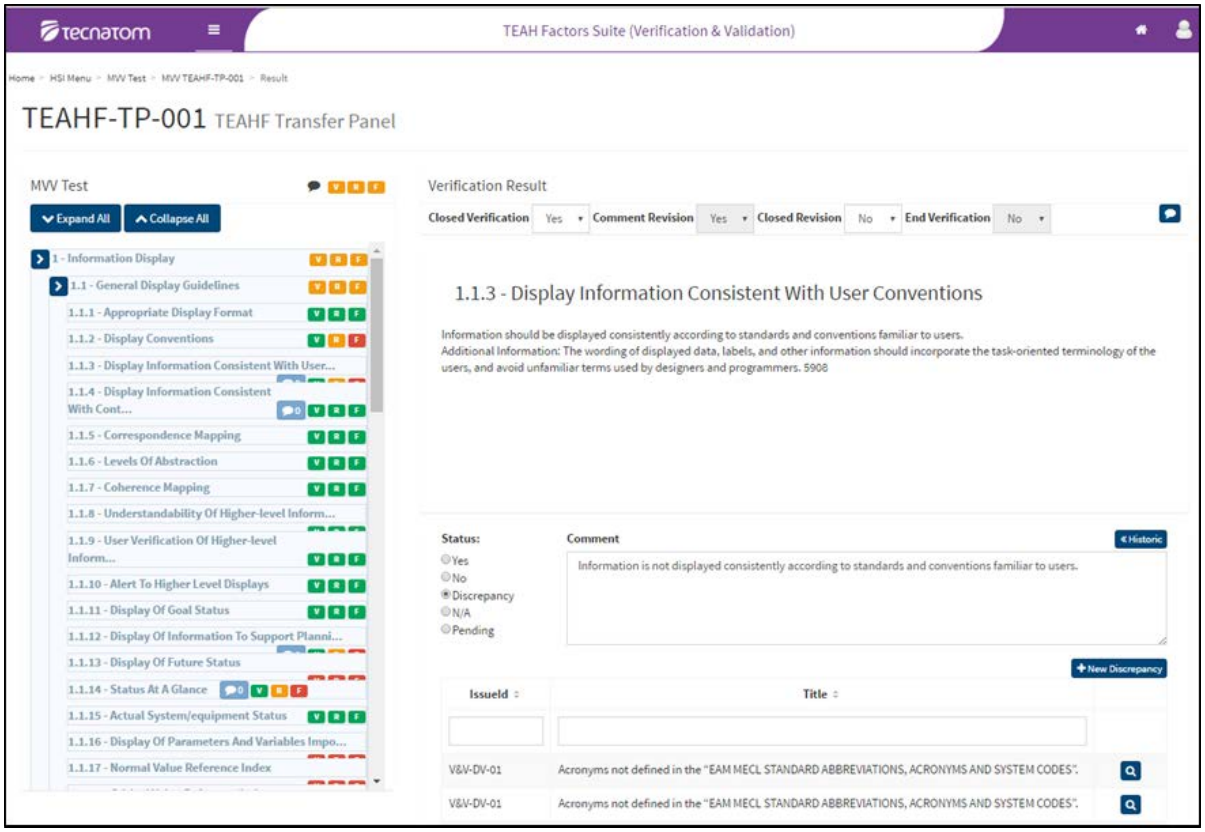

Figure 4: View of NUREG-0700 guidelines evaluation

4.4. Interfaces edition and visualization modules

TeamSketch is a graphic editor software developed by Tecnatom to support the design of Human System Interfaces. The editor provides galleries with the elements to include in the interfaces it enables the designers to create and modify prototypes and elements included in its gallery. TeamSketch tools are linked to analysis and design tools through the SQL database avoiding discrepancies and reducing execution times.

5. CONCLUSIONS

There is no need to mention the benefits and the need in the nuclear industry to continuously improve our practices. The benchmarking activities are a perfect way to assess our capacities and identify weaknesses. In Tecnatom's experience, there is much to do to improve Human Factors Engineering related activities, getting the greater benefits of them and optimizing the effort to execute them. A support tool like our integrated TEAH Factors Suite provides (when based on sound methodologies) the means to do so by:

- Improving communication and documentation control using a common platform like Microsoft SharePoint for Project Management
- Reducing the dependency on physical mock-ups using virtual ones prepared with a graphic editor with some basic simulation capabilities.

- Enabling the team members to easily create prototypes of the interfaces and providing the means to review them with the end users via web
- Using an integrated set of tools for the analysis, design and evaluation process, applying sound configuration control practices and automating the design control where possible.

6. ACKNOWLEDGMENTS

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