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Trends in HFE Methods and Tools and Their Applicability to Safety Reviews

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ABSTRACT

The U.S. Nuclear Regulatory Commission's (NRC) conducts human factors engineering (HFE) safety reviews of applicant submittals for new plants and for changes to existing plants. The reviews include the evaluation of the methods and tools (M&T) used by applicants as part of their HFE program. The technology used to perform HFE activities has been rapidly evolving, resulting in a whole new generation of HFE M&Ts. The objectives of this research were to identify the current trends in HFE methods and tools, determine their applicability to NRC safety reviews, and identify topics for which the NRC may need additional guidance to support the NRC's safety reviews. We conducted a survey that identified over 100 new HFE M&Ts. The M&Ts were compared to identify general trends. Seven trends were identified: Computer Applications for Performing Traditional Analyses, Computer-Aided Design, Integration of HFE Methods and Tools, Rapid Development Engineering, Analysis of Cognitive Tasks, Use of Virtual Environments and Visualizations, and Application of Human Performance Models. We assessed each trend to determine its applicability to the NRC's review by considering (1) whether the nuclear industry is making use of M&Ts within each trend, and (2) whether the M&Ts could be reviewed using existing design review guidance. We identified three trends as applicable to the commercial nuclear industry and expected to impact safety reviews: Analysis of Cognitive Tasks, Use of Virtual Environments and Visualizations, and Application of Human Performance Models. These trends may be considered for review guidance development.

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ABBREVIATIONS

ACTA	applied cognitive task analysis
AIM	authoring instructional materials
ATEAMS	afloat, training, exercise, and management system
C3TRACE	Command, Control, and Communication Techniques for Reliable Assessment of Concept Execution
CARE	computer aided requirements engineering
CASHE-PVS	Computer Aided Systems Human Engineering Performance Visualization System
CCAB	Complex Cognitive Assessment Battery
CMS	computerized maintenance system
CREATE	Control Room Engineering Advanced Toolkit Environment
CSDT	Crew Station Design Tool
DDSM	directory of design support methods
DELMIA	Digital Enterprise Lean Manufacturing Interactive Application
DoD	Department of Defense
DOORS	Dynamic Object Oriented Requirements System
DUTCH	Designing for Users and Tasks Form Concepts to Handles
ECAT	Engineering Control Analysis Tool
EPIC	Executive Process Interactive Control
EPRI SHP	Electric Power Research Institute Strategic Human Performance
FAST	Fatigue Avoidance Scheduling Tool
HCDA	Human Centered Design Advisor
HFE	human factors engineering
ICS-CTA	Interactive Cognitive Subsystems to Cognitive Task Analysis
IMPRINT	Improved Performance Research Integration Tool
INSAG	International Nuclear Safety Advisory Group
IPME	Integrated Performance Modeling Environment
IRqAR	Integral Requisite Analyzer
ISMAT	Integrated Simulation Manpower Analysis Tool
JASS	Job Assessment Software System
KARMA	Knowledge-based Augmented Reality For Maintenance Assistance
M&T	methods and tools
MABTA	Multiple Aspect Based Task Analysis
MIDA	Multi-Modal Interface Design Advisor
MIDAS	Man-machine Integration Design And Analysis Systems
MITes	Massachusetts Institute of Technology Environment Sensors
MVTA	Multimedia Video Task Analysis
NPP	nuclear power plant
NRC	U.S. Nuclear Regulatory Commission
NTMPS	Navy Training Management and Planning Systems
PHRED	Plant-human Review Engineering Directorate
PROCEL	Procedures Electroniques
PSF	performance shaping factor
RFID	radio frequency identification
SALT	Spatial Analysis Link Tool
SCADE	Safety Critical Application Development Environment
ShipSHAPE	Ship System Human Systems Integration for Affordability and Performance Engineering

TacWISE	Tactical Warfare Instructional Support Environment
TAWL	Task Analysis Workload
TDFA	top-down function analysis
U2T	Unified Modeling Language to Task Extraction Tool
WISP	Wireless Identification and Sensing Platform
VR	virtual reality
V&V	verification and validation

1 INTRODUCTION

1.1 Background

Technological developments are giving rise to a new generation of commercial nuclear power plants (NPPs). Just as plant technology is changing, so are the methods and tools (M&Ts) used to analyze, design, and evaluate the human factors engineering (HFE) aspects of NPPs. Advances in the M&Ts used by HFE professionals are revolutionizing the ways HFE programs are accomplished. A recent National Research Council study (Pew & Mavor, 2007) of HFE as part of system design noted:

> The field of design is also undergoing rapid change at this time. There is continued pressure to reduce the design cycle time. Software and hardware development methodologies supporting the design process are proliferating, but there is little understanding of which tools and methods are best for which purposes. Similar methods and tools are created by different communities of practice with little awareness of the tools and best practices in the related fields. There has been no comprehensive framework to organize competing methods, and, as a result, comparisons tend to be situational with correspondingly limited generalizability. (p. 12)

These changes are impacting the commercial nuclear industry as well. HFE safety reviewers will be evaluating these new M&Ts during the licensing reviews conducted by the United States (U.S.) Nuclear Regulatory Commission (NRC). It is possible that new review guidance will be needed to support those efforts. The availability of up-to-date review guidance helps to ensure that NPP personnel have the knowledge, information, capability, work processes, and working environment (physical and organizational) to safely perform their tasks.

To help ensure that its review guidance remains up-to-date, the NRC sponsored research to identify potential human performance issues associated with emerging technology in the nuclear industry, to prioritize the issues, and to develop the technical bases needed to address those of particular importance (O'Hara et al., 2008a; O'Hara et al., 2008b). The study identified 64 issues which were organized into seven topic areas:

- Role of Personnel and Automation
- Staffing and Training
- Normal Operations Management
- Disturbance and Emergency Management
- Maintenance and Change Management
- Plant Design and Construction
- HFE Methods and Tools

As part of the issue identification process, five nuclear power industry HFE subject matter experts (SMEs) evaluated the reasonableness of the issue identification methodology and the completeness of the issues identified during a workshop (Brown & O'Hara, 2004). In addition, the SMEs were to identify what they considered to be the key issues. There was consensus that HFE M&T issues are the most important. The SMEs indicated that it is essential to have explicit review criteria for an applicant's design methodology to ensure that important safety issues are identified and addressed for each new reactor design.

In a second workshop, 14 SMEs formally prioritized the issues into four categories using a "Phenomena Identification and Ranking Table" methodology (O'Hara, 2008a). The SMEs were knowledgeable in a variety of disciplines and included representatives of vendors, utilities, research organizations and regulators. Of the 64 issues, twenty were categorized into the top priority category. Almost half of these top-priority issues belong to the HFE Methods and Tools topic. The importance of the design process was one of the major themes discussed during the workshop. SMEs agreed that the HFE design process is the single most important topic for addressing the safety of future plants. M&Ts are significant in the context of HFE safety reviews because the NRC evaluates the M&Ts used in the course of an applicant's design process. A design-process approach helps to standardize the NRC's safety evaluations across a diversity of new reactor types because M&T review criteria are technology neutral (see Section 1.2). As HFE M&Ts rapidly change, modifications and improvements to the NRC's review methods and criteria may be necessary.

The NRC's research findings on the importance of HFE M&Ts to safety is consistent with the the National Research Council study referenced earlier (Pew & Mavor, 2007). The Council identified the major reasons systems fail (see Table 1-1). Of the 15 reasons identified, most have to do with various aspects of the design process and the M&Ts used by HFE practitioners.

In the next section we will discuss the role of HFE M&Ts in the NRC's review of the HFE aspects of nuclear plants.

1.2 The Role of HFE Methods and Tools in HFE Safety Reviews

To appreciate the importance of HFE M&Ts, it is important to understand the purpose of the HFE reviews conducted by the NRC and the technical basis upon which the review guidance was established.

Human Factors and Plant Safety

The International Nuclear Safety Advisory Group (INSAG) of the International Atomic Energy Agency (IAEA) identified the technical safety objective for nuclear power plants (INSAG, 1999):

> To prevent with high confidence accidents in nuclear plants; to ensure that, for all accidents taken into account in the design of the plant, even those of very low probability, radiological consequences, if any, would be minor; and to ensure that the likelihood of severe accidents with serious radiological consequences is extremely small. (p. 10)

Ensuring plant safety requires "defense-in-depth." Defense-in-depth includes the use of multiple barriers to prevent the release of radioactive materials and a variety of programs to ensure the integrity of barriers and related systems. These programs include, among others, conservative design, quality assurance, administrative controls, safety reviews, personnel qualification and training, test and maintenance, safety culture, and human factors.

Table 1-1 National Research Council's Reasons Systems Fail

• Failure to introduce human factors considerations early enough - in some cases, needs and requirements are forecast even before the formal system acquisition process begins.
• Lack of effective methods and tools to predict direct impacts and ripple effects of envisioned future systems early in the design process, particularly in the case of large-scale systems and "systems of systems" with diverse elements that can interact in complex ways that are difficult to anticipate.
• A tendency to focus on people as the error-prone weak links in a system that need to be "automated away," rather than as important contributors to overall system resilience that enable systems to adapt to unanticipated situations who need support in that role.
• Failure to apply recognized good practices, such as those specified in Department of Defense (DoD) and international quality standards (ISO).
• Lack of ability to abstract generalizable concepts and principles, as well as transportable models, across application contexts, limiting the ability to grow a solid body of human factors design knowledge.
• Lack of synergy between research and practice, with the result that practitioners are not sufficiently aware of relevant research and research is not sufficiently informed by the body of knowledge gained from practice.
• Lack of adequate HSI metrics to support progress monitoring, pass/fail reviews, and system-level evaluation.
• Inadequate or poorly documented data on relevant human task performance.
• Lack of effective use of methods and tools to support the HSI process.
• Difficulty justifying the cost of resource allocation to study and resolve HSI issues.
• Inadequate education and training of system developers to sensitize them to the HSI issues.
• Limited opportunities for the education of HSI specialists.
• Failure to assign necessary resources to address HSI concerns due to a lack of awareness that the resources are needed.
• Conflicting requirements of various stakeholders in the system development process.
• Insufficient advocacy for HSI considerations at top organizational levels.

Note: The information in this table is from Pew and Mavor (2007), pp. 14-15. In this table, the acronym "HSI" refers to "human-system integration."

HFE plays a significant role in supporting plant safety and providing defense-in-depth. IAEA states:

> One of the most important lessons of abnormal events, ranging from minor incidents to serious accidents, is that they have so often been the result of incorrect human actions. Frequently such events have occurred when plant personnel did not recognize the safety significance of their actions, when they violated procedures, when they were unaware of conditions of the plant, were misled by incomplete data or incorrect mindset, or did not fully understand the plant in their charge. (p. 27, IAEA, 1999)

Thus, HFE was established as a principle that is essential to the successful application of safety technology for NPPs. The principle states:

> Personnel engaged in activities bearing on nuclear power plant safety are trained and qualified to perform their duties. The possibility of human error in nuclear power plant operation is taken into account by facilitating correct decisions by operators and inhibiting wrong decisions, and by providing means for detecting and correcting or compensating for error. (p. 27, IAEA, 1999)

The IAEA further states that "attention to human factors at the design stage ensures that plants are tolerant to human error" (p. 19, IAEA, 1999).[1]

The regulatory basis for HFE reviews in the U.S. is consistent with these international principles. In accordance with the U.S. Code of Federal Regulations (CFR), Title 10 - Part 52, the NRC reviews the HFE programs of applicants for construction permits, operating licenses, standard design certifications, and combined operating licenses. The purpose of these reviews is to help ensure safety by verifying that acceptable HFE practices and guidelines are implemented in the applicant's HFE program.

10 CFR 52.47 requires that applications for certification of new reactor designs meet the technically relevant portions of the Three Mile island (TMI) requirements contained in 10 CFR 50.34(f) (except for 10 CFR 50.34(f)(1)(xii), (f)(2)(ix), and (f)(3)(v)). The NRC bases its HFE review on current regulatory requirements established post-TMI in 10 CFR 50.34(f), "Additional TMI-Related Requirements." The NRC reviews HFE aspects of new control rooms to verify that they reflect "state-of-the-art human factors principles" as required by 10 CFR 50.34(f)(2)(iii) and that personnel performance is appropriately supported.

For plants licensed under 10 CFR Part 52, the requirements of 10 CFR 50.34(f) are incorporated via 10 CFR 52.47 and 10 CFR 52.79. Meeting these requirements provides evidence that plant design, staffing, and operating practices are acceptable and that there is reasonable assurance that plant safety will not be compromised by human error or by deficiencies in human-system interfaces (HSIs).

The need for a programmatic approach to human factors is similarly identified in other sections of the CFR. For example, applicants are required to:

> Provide, for Commission review, a control room design that reflects state-of-the-art human factors principles prior to committing to fabrication or revision of fabricated control room panels and layouts [10 CFR 50.34(f)(2)(iii)]

> Establish a program... for integrating and expanding current efforts to improve plant procedures. The scope of the program shall include emergency procedures, reliability analyses, human factors engineering, crisis management, operator training...[10 CFR 50.34(f)(2)(ii)]

The NRC process of reviewing an aspect of a nuclear power plant (NPP) to ensure that it meets requirements and that it will perform as needed to reliably ensure plant safety is called a "safety evaluation." This evaluation includes an HFE safety evaluation.

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[1] For a more detailed discussion of the role of human performance in plant safety, see NUREG-6947 (O'Hara et al., 2008).

Technical Basis for NRC HFE Review Guidance

Although 10 CFR Part 50 provides the regulatory basis for conducting HFE reviews, it does not prescribe how these reviews will be performed. One of the NRC's responses to the TMI accident was to develop an action plan to address nuclear plant safety (NRC, 1980). Issue 1.D.1 of the action plan required licensees and applicants to perform detailed control room design reviews to identify and correct HFE deficiencies. Issue I.D.2 required the development of a safety parameter display system (SPDS) to improve safety function monitoring. Detailed guidance for conducting control room reviews was provided in NUREG-0700 (NRC, 1981a).[2] In addition, the NRC developed Chapter 18, Human Factors Engineering, of the Standard Review Plan (NUREG-0800) (NRC, 1984) to provide high-level guidance to support reviews of licensees' submittals. This guidance served its purpose for over a decade; however, changes in the industry led the NRC staff to take a fresh look at how HFE reviews were performed. The most significant changes were (1) the submittal of design certification applications under 10 CFR Part 52, and (2) the emergence of digital instrumentation and control (I&C) and computer-based HSIs.

With respect to design certification submittals, complete and detailed descriptions of the HFE aspects of the plant, i.e., the HSIs, procedures, and training, are not typically provided to the NRC staff for review. One reason for this is that the NRC and the nuclear industry recognized that computer-based HSIs (and digital I&C systems in general) evolve very quickly as new technology is continuously being developed. For the first design certification submittal (e.g., the Advanced Boiling Water Reactor), the NRC and industry expected that the time between certification and plant construction would be long. Thus, it seemed prudent to delay detailed design to a time close to construction so the designs could take advantage of new technological developments and innovations. In lieu of design details, the applicant described the process to be used to design and implement the HFE aspects of the plant. Further, the HSI technology being to be designed was computer-based. Since at the time the staff's HFE review guidance focused on the detailed design of analog control rooms rather than the process used to develop and implement computer-based HSIs, new guidance was needed to support the design certification reviews.

The NRC conducted a study to expand its HFE review guidance to address the design process and computer-based HSIs (see O'Hara, 1994 for a full description of this study). The study concluded the review approach should have the following characteristics:

1. The HFE evaluation methodology should have broad application to review upgrades to existing plants, as well as new HSI design concepts.
2. The methodology should encompass the review of a broad range of HSI designs and a diversity of approaches to advanced HSI technology. The guidance should focus heavily on the human-software interface because this is where the most significant human performance issues reside, and where NRC additional review guidance is needed.
3. The methodology should provide guidance for conducting reviews throughout the design life cycle, i.e., proposed/conceptual design to final design, because:

[2] The NRC used NUREG-0737, "Clarification of TMI Action Plan Requirements," Supplement 1 (NRC, 1980), NUREG-0835 (NRC, 1981b), and NUREG-1342 (NRC, 1989) for SPDS review guidance. The guidance has been incorporated into Section 5 of NUREG-0700, Rev 2 (O'Hara et al., 2002).

- Reactor design certification reviews will address HSIs described only at conceptual levels of detail
- Many significant human factors issues arise early in design, e.g., initial goals/objectives of the design and allocation of function

4. An applicant's HSI evaluation should extend beyond checklist-based HFE guideline evaluations and include validations of the fully-integrated system under realistic, dynamic conditions using operators trained to perform the tasks for which the HSI was designed (including various types of failures and transient conditions). The reasons validation should be included are:
   - A final design review using HFE guidelines alone is not sufficient to ensure a safe, acceptable design as these guidelines typically do not address task requirements or the effects of human interaction with a dynamic system.
   - The state of knowledge about the effects of advanced technology on human performance, especially under abnormal plant conditions, is limited; correspondingly, the technical basis for developing complete, comprehensive, and valid guidelines is limited.

Development of a New Approach to Reviewing the HFE Aspects of NPPs

The first step in developing a new approach was to identify which elements of the design process are most effective to assure that HFE design goals in support of plant safety are achieved. Next, we identified the review criteria by which each element could be assessed. The results were published in the HFE Program Review Model (PRM), NUREG-0711[3] (O'Hara et al., 1994). The specific objectives of the HFE PRM development effort were:

- To develop a technical basis for the review of an applicant's HFE design process and final design implementation. The NRC's HFE PRM should be: (1) based upon currently accepted HFE practices, (2) well-defined, and (3) based on an approach which has been validated through its application to the development of complex, high-reliability systems.
- To identify the HFE elements in a plant/system development, design, and evaluation process that are necessary and sufficient for the successful integration of personnel into plant design and operations.
- To identify the components of each HFE element that are key to a safety evaluation.
- To specify the review criteria by which HFE elements can be evaluated.

A review of then-current HFE guidance and practices was conducted to identify important HFE program plan elements relevant to the technical basis of a design process review. Several types of documents were evaluated:

- Systems theory and engineering - general literature providing the theoretical basis for systems engineering, e.g. Gagne and Melton, 1988.
- NPP regulation - the regulatory basis for NPP review and related NRC literature, e.g., 10CFR50, 10CFR52, NUREG-0800, and NUREG-0700 - Appendix B.

[3] While the first publication of NUREG-0711 was in 1994, the review guidance was used for the first design certification review – the ABWR. The guidance was published as Appendix J of the ABWR Safety Evaluation Report (NUREG-1503, NRC 1994).

- General HFE guidance - HFE guidance developed to be generally applicable to the design and evaluation of complex systems, e.g., Military handbook (MIL-H) 46855 (DoD, 1979).
- NPP HFE guidance - standards, guidance, and recommended practices developed in the NPP industry, e.g., the Institute of Electrical and Electronics Engineers (IEEE) STD 1023-1988 (IEEE, 1988), International Electrotechnical Commission (IEC) 964 (IEC, 1989), and EPRI Advanced Light Water Reactor Requirements (ALWR) Utility Requirements Document (EPRI, 1990).

From this review, we defined a process of HFE development, design, and evaluation. Key HFE elements were identified and general criteria were developed with which these elements could be assessed. The HFE PRM development was based largely on applied general systems theory (Bailey, 1982; DeGreene, 1970; Gagne et al., 1988; Van Cott & Kinkade, 1972; Woodson, 1981) and the DoD system development process which is rooted in systems theory (DoD, 1979; DoD, 1990,b; Kockler et al., 1990). The importance of treating the human factors as integral aspects of the design was well documented in both general systems engineering standards and in the U.S. military's system acquisition process. For example, the IEEE systems engineering standard (IEEE Standard 1220-1998)[4] states:

> The design of the products and life cycle processes should consider the human as an element of the system in terms of operators, maintainers, manufacturing personnel, training personnel, etc. for the purpose of understanding the human/system integration issues and ensuring that the system products are producible, maintainable, and usable. (p. 3-4)

Similarly, MIL-HDBK-46855, which provides HFE requirements for military systems, states:

> Human engineering (HE) should be applied during development and acquisition of military systems, equipment, and facilities to integrate personnel effectively into the design of the system. An HE effort should be provided to (a) develop or improve all human interfaces of the system; (b) achieve required effectiveness of human performance during system operation, maintenance, support, control, and transport; and (c) make economical demands upon personnel resources, skills, training, and costs. The HE effort should include, but not necessarily be limited to, active participation in the following three major interrelated areas of system development: analysis, design and development, and test and evaluation. (p. 8)

Systems engineering provides a broad approach to system design based on a series of clearly defined developmental steps, each with defined goals, and with specific processes to attain them. System engineering has been defined as "...the management function which controls the total system development effort for the purpose of achieving an optimum balance of system elements. It is a process which transforms an operational need into a description of system parameters and integrates those parameters to optimize the overall system effectiveness" (Kockler et al., 1990). DoD design requirements reflect this approach. As noted above, personnel are identified as a specific component of the total system (DoD, 1990a). All system components (hardware, software, personnel, support, procedures, and training) are given detailed consideration in the design process. The process is formalized and contains detailed design process requirements.

Within the DoD system, the development of a complex system begins with the mission or purpose of the system, and the requirements needed to satisfy mission objectives. The

[4] Other systems engineering standards include: ANSI/EIA 632-1999 (ANSI, 1999) and ISO/IEC 15288 (ISO, 2008).

effective integration of HFE considerations into the design is accomplished by: (1) providing a structured top-down approach to system development which is iterative, integrative, interdisciplinary and requirements driven, and (2) providing a management structure which details the HFE considerations in each step of the overall process. A structured top-down approach to NPP HFE is consistent with the approach to new HSI design described in Appendix B of NUREG-0700 (U.S. NRC, 1981b) and nuclear industry standards (IEC, 1989; IEEE, 1988). The approach is also consistent with the recognition in the nuclear industry that human factors issues and problems emerge throughout the NPP design process and, therefore, human factors issues are best addressed with a comprehensive top-down program (for example, see Beattie and Malcolm, 1991; Stubler, Roth, and Mumaw, 1991). Together with applicable NRC HFE requirements, the systems engineering approach served as the basis for the development of the HFE PRM.

NRC HFE Review Guidance

HFE guidance for the regulatory review of NPPs is addressed in Chapter 18, *Human Factors Engineering* of the Standard Review Plan (NRC, 2007a). Section II.A provides the high-level acceptance criteria for the review of the HFE aspects of new plants. The NRC's approach is based on the concept that the HFE aspects of new reactors should be developed, designed, and evaluated on the basis of a structured systems analysis using accepted HFE principles. This approach is reflected in three key principles adapted from systems engineering that form the foundation for the staff's review methodology and guidance.

The first is that HFE must be integrated into the overall engineering design process. The integration will help ensure timely and complete interaction with other engineering activities.

The second principle is that the HFE aspects of the plant should be developed, designed, and evaluated on the basis of a systems analysis that uses a "top-down" approach. Top-down refers to an approach starting at the "top" of the hierarchy with the plant's high-level mission and goals (see Figure 1-1). The mission/goals are divided into the functions necessary to achieve the goals. Functions are allocated to human and system resources. Each function can be broken down into tasks. The tasks are analyzed to identify the alarms, displays, procedures, controls, etc. that will be required for task performance. Task requirements reflect performance demands imposed by the detailed design of the system. Tasks are arranged into meaningful jobs to be performed by personnel who will operate and maintain the system. The interfaces, support systems, procedures, and training are designed to best support personnel in performing their tasks. The detailed design (of the interfaces, support systems, procedures, and training) is the "bottom" of the top-down process. Of course, there are also requirements that stem from the detailed design of individual systems and components. These are captured when personnel tasks are analyzed.

The third principle is that HFE should be considered for the full life cycle of the plant; i.e., concept planning, detailed design, operations, and decommissioning/disposal. Personnel needs should serve as input to early design decisions, e.g., if an operation should be automated; therefore, HFE activities should begin early in the design process.

Figure 1-1 Top-down Approach to Design

These principles provide the foundation upon which the staff's detailed review criteria are developed. These criteria are provided by the *Human Factors Engineering Program Review Model* (NUREG-0711, NRC 2004b), which is referenced by Chapter 18 of the Standard Review Plan. The criteria are organized into twelve areas of review, as is illustrated in Figure 1-2.

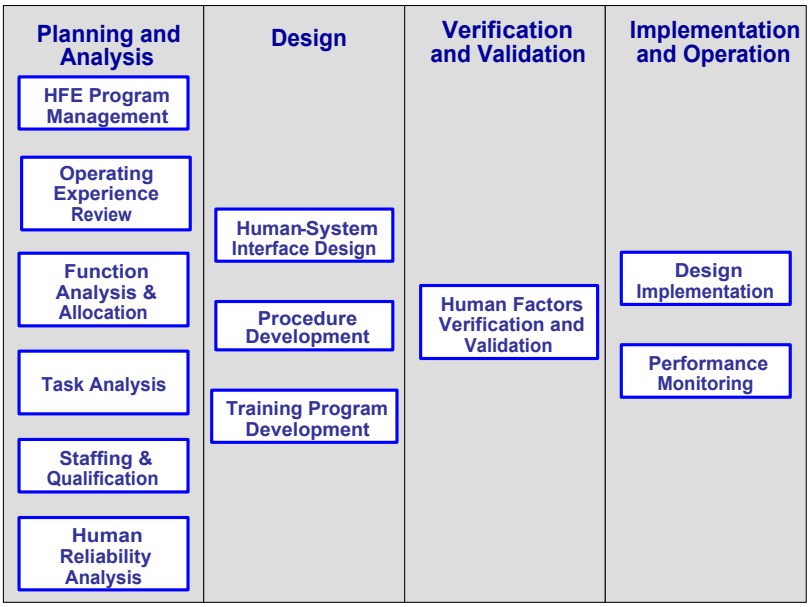

Figure 1-2 NUREG-0711 HFE Review Elements

The types of information that contribute to an assessment of the adequacy of an applicant's HFE program include:

- HFE planning (including an HFE design team, program plans, and procedures)
- design analyses and studies (including requirements, function and task analyses, technology assessments, tradeoff studies)
- design specifications and descriptions

- verification and validation (V&V) of the final design (e.g., compliance with accepted HFE guidelines and operation of the integrated system with operators performing the required tasks under actual (or simulated) conditions)

The greatest confidence in a finding that a design acceptably supports plant safety can be placed in one that has the following characteristics:

- The design was developed by a qualified HFE design team with the skills required, using an acceptable HFE program plan

- The design was based on appropriate HFE studies and analyses that provide accurate and complete inputs to the design process and inputs to V&V assessment criteria

- The design used proven technology based on human performance and task requirements incorporating accepted HFE standards and guidelines

- The design was evaluated with a thorough V&V test program that includes high-fidelity simulator exercises.

Therefore, the HFE M&Ts used by an applicant are an important aspect of the staff's review of the HFE aspects of new reactors. For this reason, understanding HFE M&Ts is an important research topic associated with the evaluation of new reactor designs.

1.3 Objectives

The objectives of this research were to:

- identify the current trends in HFE M&Ts
- determine their applicability to NRC safety reviews
- identify topics for which the NRC may need additional design review guidance

1.4 Report Organization

The remainder of this report is divided as follows. Section 2 describes the research methodology. Section 3 provides the results of the study. Section 4 discusses the results and recommended next steps. Section 5 gives the full references for cited works.

In addition, the report has two appendices. Appendix A includes brief descriptions of the methods, techniques, tools, and technologies along with references or sources of additional information. Appendix B includes a table that cross-references the methods, techniques, tools, and technologies to the NRC's HFE review elements of NUREG-0711.

2 METHODOLOGY

An overview of the methodology used in this study is shown in Figure 2-1.

Figure 2-1 Technical Approach

Survey of Advances in HFE Methods and Tools

Our objective in conducting the survey was to identify a reasonable sample of M&Ts being developed and used by HFE practitioners. This was not an effort to identify all new M&Ts. For all practical purposes, such an effort is impossible since new approaches are constantly being developed. However, by identifying a reasonable sample, we have a basis to identify the major trends and M&T classifications.

We reviewed the HFE literature to identify new M&Ts, including key compendia such as:

- Defense Technical Information Center - Directory of Design Support Methods (DDSM) (Defense Technical Information Center, 2007). According to the document's preface, "The DDSM provides an annotated directory of human systems integration (HSI) design support tools and techniques that have been developed by the DoD, NASA, FAA, NATO countries, academia, and private industry… The DDSM contains references to design tools or techniques that are currently available or under development. New records continue to be added as new human systems tools and techniques are developed." (p. v) The document is also maintained and updated online at: http://www.dtic.mil/dticasd/ddsm/.
- Human Engineering Process Tools List (Office of Naval Research, 1998)
- Human Engineering Program Process and Procedures Military Handbook (DoD, 1999)

We obtained additional information through contacts with organizations and individuals involved with the M&Ts.

NUREG-0711 was used as a framework to both conduct the search and to organize the results.

Identify Major Trends

We evaluated the M&T survey results to identify new trends that are changing the way HFE practitioners perform their tasks and which are likely to influence the design of key HFE aspects of a plant. To identify the trends, the project staff discussed the similarities between the M&T and ways in which they could be grouped. No formal evaluation criteria were applied.

The reason for identifying the trends in M&Ts rather than treating each on its own merits has to do with review guidance development. There are hundreds of individual HFE M&Ts available to HFE practitioners and new approaches are continuously being developed. Thus, it is

impractical to attempt to develop review criteria for each individual method. Instead, review criteria can be developed for important trends, resulting in criteria that can be applied to a large number of M&Ts.

Determine Applicability to NRC Reviews

Once the trends were identified, the project team determined the applicability of the trends for NRC safety reviews by considering two questions:

1. Will the trend impact the nuclear industry; i.e., are NRC licensees and vendors likely to use the M&Ts in each category?

2. Will the trend impact the ability of the NRC staff to conduct NUREG-0711 reviews; i.e., if an applicant's submittal includes a method or tool reflecting the trend, can it be reviewed using current NUREG-0711 review guidance?

Once these questions were answered, we used the following decision logic to make recommendations concerning whether the NRC should consider additional guidance development:

- M&T trends that are largely outside the nuclear industry and not likely to be used in the foreseeable future do not need to be considered at this time.

- M&T trends that can be addressed with existing NUREG-0711 guidance do not need to be considered at this time.

- M&T trends that are applicable to the commercial nuclear industry and are expected to impact NUREG-0711 reviews may be considered for review guidance development.

3 RESULTS

3.1 Methods and Tools Survey

The search identified over 100 HFE M&Ts. A brief summary of the M&Ts pertaining to each element is given later. Due to the large number of individual M&Ts identified, each is not described in the main body of the report. Instead, each individual M&T is briefly described in Appendix A along with references to where additional information can be obtained. Note that the appendix is intended to give the readers a better understanding of the purpose and functions of the M&Ts discussed. The M&T descriptions were obtained primarily from the source materials identified in the appendix with little to no rewording. Thus, enthusiastic descriptions of the capabilities of individual M&Ts or apparent endorsements reflect the opinions of the authors of the referenced source material and do not reflect the opinions of the authors of this report.

Table 3-1 lists the numbers of M&Ts associated with each NUREG-0711 review element. As noted in Section 2, NUREG-0711 was used as an organizational framework for the M&Ts identified in the survey. Two NUREG-0711 review elements were omitted. The HFE Program Management element was not considered because it pertains to the management and staffing of the HFE program rather than the M&Ts used by HFE professionals. The Human Reliability Analysis (HRA) element was excluded from this survey because the NRC has conducted considerable research related to M&Ts in this area (e.g., NRC, 2005). Further, the NRC's HFE review addresses the integration of probabilistic risk assessment and HRA insights in the HFE program rather HRA methodology.

Many M&Ts are relevant to more than one NUREG-0711 review element. We discuss each M&T in the elements for which they most directly applies. Appendix B contains a complete cross-reference table of which HFE M&Ts are applicable to each review elements.

Table 3-1 Number of HFE Methods and Tools by Review Element

NUREG-0711 Review Element	Report Section	Number of Methods/Tools
Operating Experience Review	3.1.2	7
Functional Requirements and Function Allocation	3.1.3	22
Task Analysis	3.1.4	21
Staffing and Qualifications	3.1.5	11
Human-System Interface Design	3.1.6	20
Procedure Development	3.1.7	7
Training Program Development	3.1.8	12
Verification, Validation, and Design Implementation	3.1.9	18
Human Performance Monitoring	3.1.10	12

It is interesting to note the relationship between the evolution of systems engineering models and their impact the M&T development. As was discussed in Section 1.2, the NRC approach to HFE review was rooted in systems engineering. However, as has been emphasized in the Research Council study (Pew & Mavor, 2007), systems engineering itself is changing.

Traditionally, system design is a process that has been described as “waterfall approach.” Several other approaches (e.g., Development Lifecycle, Spiral Development, Rapid Prototyping, and Concurrent Engineering) have been introduced and applied more recently (in addition to Pew & Mavor, see Booher, 2003; Eisner, 2005; Wasson, 2006). The key features of these approaches focus on reducing development times and costs and introducing design-and-assess iterations into the development process. Although these changes may result in designs being developed more rapidly and for lower costs, the impact on safety may be a concern. Many of the more detailed M&Ts identified in later sections reflect the overarching influence of changes to the system engineering process itself.

3.1.1 Operating Experience Review

The objective of the operating experience review is to ensure that applicants have identified and analyzed HFE-related problems and issues in previous designs that are similar to the design in their current application. In this way, negative features associated with predecessor designs are avoided while positive features are retained.

Operating experience reviews generally focus on plant event reports and report summaries, summaries of operator interviews, and assessments of how the applicants design addresses HFE issues know to the industry. Plant reports may include incident tracking documentation and data collected from error management or evaluation and this information (along with operator interviews, surveys, etc.) is used to develop error prevention techniques and procedures.

Emerging approaches to operating experience reviews have developed in two areas. First, there are new sources of operating experience data based on from the application of new practices such as benchmarking and lessons-learned, as well as human knowledge capturing efforts within the nuclear power industry. Second, technologies for managing and accessing these data stores are increasingly available. The narrative character of most operating experience data makes coding the data for easy search cumbersome. Performing keyword searches can be tedious as well due to large numbers of unusable "hits" or lack of results resulting from using the wrong keywords. Table 3-2 lists several technologies and approaches for better management of this type of data.

Table 3-2 Operating Experience Data, Access, and Management

Method/Tool	Key Features
Electric Power Research Institute (EPRI) operations knowledge capture	Derived from cognitive task analysis, critical incident/decision reviews, and operations walk-throughs Provides concept maps, knowledge repositories, and communities of practice
ELETRONUCLEAR knowledge management databank	Captures knowledge from plant personnel Used to identify knowledge gaps and bottlenecks
Case Based Reasoning	Matches incidents based on similarities of problems or solutions Adapts as new incidents are integrated
Communities of Practice	Directly involves experts Typically supported by electronic collaboration tools
Department of Energy (DOE) Lessons Learned Program	Supported by a formal lessons learned community of practice Provides technical standards for lessons learned programs Links to people who can help
LearnSafe	A set of tools and methods for supporting organizational learning
Information Link Analysis	Tracks search histories and successes/failures Directs new search results based on strength of similar search histories

3.1.2 Functional Requirements Analysis and Function Allocation

The objective of the functional requirements analysis and function allocation review is to ensure that applicants have identified the functions[5] that are required to satisfy operational and safety objectives, and that functions are allocated to human and systems resources in a manner that takes advantage of human strengths and avoids human limitations.

Software development methods, tools, and techniques are playing a prominent role in functional requirements analysis and function allocation. Software tools address the process, timing, and resource requirements for function accomplishment. These approaches emphasize information flows and relationships. Techniques for articulating and capturing this information have been developed along with the approaches.

An entire class of tools based on task network modeling has emerged for performing function allocation analyses and trade-offs. Task network modeling is an approach to simulating tasks and their relationships based on task and human performance characteristics. These tools can also be used for task analysis, manpower and personnel analysis, and training-gap analysis.

Based on the above, technologies for functional requirements analysis and function allocation have been divided into the following areas: Requirements management, information analysis, and function allocation. Tables 3-3 through 3-5 reflect each of these areas respectively.

[5] In this context, a “function” is a process or activity that is required to achieve a desired goal. For example, safety functions prevent or mitigate the consequences of postulated accidents that could damage the plant or cause undue risk to the health and safety of the public.

We obtained much of the information about the Requirements Management and Information Analysis M&Ts from the International Council on Systems Engineering (INCOSE) Tools Database Working Group (INCOSE, 2005). Industry experts evaluated a comprehensive list of commercially available Requirements Management tools and identified the key features of each along with the criteria used to evaluate them. The key features and evaluation criteria are intended to support designers in finding the most appropriate tools and can serve as a method for comparing them.

The tools and methods included in the list of Requirements Management M&Ts (Table 3-3) are limited to managing requirements; where as, the tools contained in the list of Information Analysis M&Ts (Table 3-4) are broader in scope and may also be used in the system design process for activities such as modeling. Note the M&Ts listed in Table 3-4 are at a system-level (in contrast to task analysis level), thus they are included here.

Table 3-3 Requirements Management Methods and Tools

Method/Tool	Key Features
Analyst Pro	Easy requirements tracking and documentation Supports most systems engineering approaches
Computer Aided Requirements Engineering (CARE)	Supports complex projects well Supports large distributed teams well
CORE product family	Supports a wide range of systems engineering approaches and tools Supports software systems/data modeling
Dynamic Object Oriented Requirements System (DOORS)	Object oriented approach to requirements management
EasyRM	Computer Aided Software Engineering (CASE) tool supports early stages of the project lifecycle
Human Centered Design Advisor (HCDA)	Human factors requirements advisor
IBM Rational Clear Case and Clear Quest	Complete software life-cycle management tool suite
Integral Requisite Analyzer (IRqA)	Requirements life-cycle management tool
Objectiver	Goal driven requirements engineering tool

Table 3-4 Information Analysis Methods and Tools

Method/Tool	Key Features
Data Flow Diagrams	Structured approach to illustrating data flows
Entity Relationship Diagrams	Structured approach to illustrating data attributes and relationships to other data elements
Foresight	Data modeling tool
Information Engineering	Takes holistic approach to data flows and relationships
Object Oriented Approaches	Views system as a collection of interacting objects that exchange information and change states
Cognitive Work Analysis	Cognitive analysis that focuses on the system

Table 3-5 Function Allocation Methods and Tools

Method/Tool	Key Features
Business Process Modeling	Articulates the "who, what, when, where, why" of business processes Supported by Business Process Engineering Language (BPEL) software
C3TRACE (Command, Control, and Communication Techniques for Reliable Assessment of Concept Execution)	Command and control team information flow
Improved Performance Research Integration Tool (IMPRINT)	Enables trade-offs between human resources, system-human function allocation, and system performance Army/military based
Plant-Human Review & Effectiveness Decision Tool (PHRED)	IMPRINT adapted to nuclear power operations
Ship System Human Systems Integration for Affordability and Performance Engineering (ShipSHAPE)	A suite of manpower analysis tools that include function allocations
Top Down Function Analysis (TDFA)	Top down function analysis
Scenario Based Function Allocation	Holistic approach to function allocation

3.1.3 Task Analysis

The objective of a task analysis review is to verify that the applicant's analysis identifies the specific tasks that are needed for function accomplishment and each task's information, control, and task-support requirements. Task analysis is at the heart of the HFE discipline and includes over 100 different methods, some dating back to over 100 years ago (Diaper, 2004). The centrality of task analysis to HFE design and evaluation is recognized within NUREG-0711 as well. According to Stanton (2004), task analysis methods use one of five types of task representations: hierarchical lists, narrative, flow diagrams, hierarchical diagrams, and tables.

Kirwan (1992) continues to be the standard text for conducting task analysis, but recent works reflect its changing nature, e.g., Diaper (2004) and Crandall et al. (2006). These new task analysis methods are evolving in the following directions:

- Increased use of cognitive task analysis (CTA) methods
- Increased use of collaborative task analysis
- Increased user participation in data analysis and representation
- Increased use of computer-assisted software engineering (CASE) tools
- Integration of task analysis and software specification
- Increased focus on situational awareness
- Increased use of methods yielding faster results
- Better inclusion of environmental context
- Better inclusion of group work in task analysis

New task analysis methods that follow the above trends are listed in Table 3-6. Three classes of task analysis M&Ts deserve additional attention due to the number and diversity of approaches they encompass – Cognitive Task Analysis, Task Network Modeling, and Computer Assisted Software Engineering.

Cognitive Task Analysis

CTA focuses the analysis on cognitive skills that personnel must possess to perform various tasks. CTA is widely used in the analysis of complex tasks where the emphasis is decision making rather than physical work. CTA is typically divided into three phases: Knowledge elicitation, data analysis, knowledge representation. CTA methods have broad application areas such as training development, information systems design, procedure design, and HSI design.

Task Network Modeling Tools

Task network modeling tools, as implied by the name, represent tasks as a series of nodes and links that create networks. Networks can be embedded within networks to allow for varying levels of detail. Decision logic, such as an "if..., then…" statement, is included for the links to describe the paths or sequences of tasks, and recursion or looping of tasks can be included. Tasks typically have times or time distributions defined by the analyst. Operators and other personnel resources can be consumed by tasks and demands for them reflected as part of the models. Error rates can also be introduced. These task network models can then be exercised across a range of scenarios to capture data on system and human performance.

Data from task network models can provide a robust representation of the performance of personnel across the range of operational conditions. Models can easily incorporate the various conditions that may affect human performance and human performance variability, such as cognitive workload and situation awareness. Although human performance models historically have incorporated plant or system representations of limited fidelity, human performance models can now be linked to more sophisticated plant or system simulations.

Computer Assisted Software Engineering Tools

Computer-assisted software engineering (CASE) tools were originally created to support software development, but have a very strong task analysis component. According to Paris (2004), CASE tools fall into three categories: task model editors, text analysis tools, and task event recorders. Task model editors lend computer support when creating a model of the relationship between individual tasks. With text analysis tools, the analyst can manually or automatically (using a natural language parser) generate tasks from written task descriptions,

scenarios, or instructions. An event task recorder can record user subtasks in performing tasks. Some tools combine all three into a "task modeling environment." An additional type of CASE tools allows the translation or importing of models from one method of analysis to another. A good summary of these tools can be found in van Welie (2001).

Table 3-6 New Task Analysis Methods and Tools

Method/Tool	Key Features
Applied Cognitive Task Analysis (ACTA)	Cognitive task analysis
Cognitive Archeology	Cognitive task analysis
Cognitive System Design	Cognitive task analysis
Cognitive Work Analysis	Cognitive task analysis
Command, Control & Communication - Techniques for Reliable Assessment of Concept Execution (C3TRACE)	Task network modeling tool
Designing for Users and Tasks from Concepts to Handles (DUTCH)	Group work
Engineering Control Analysis Tool (ECAT)	Task network modeling tool
Improved Performance Research Integration Tool (IMPRINT)	Task network modeling tool
Integrated Performance Modeling Environment (IPME)	Task network modeling tool
Interactive Cognitive Subsystems to Cognitive Task Analysis (ICS-CTA)	Cognitive task analysis
Isolde: Unified Modeling Language to Task Extraction Tool (U2T)	CASE tool
Multiple Aspect Based Task Analysis (MABTA)	Group work
Multimedia Video Task Analysis (MVTA)	Video task analysis
Participatory Task Modeling	User participation
Plant-Human Review & Effectiveness Decision Tool (PHRED)	Task network modeling tool
Ship System Human Systems Integration for Affordability and Performance Engineering (ShipShape)	Traditional task analysis
SkillsNet	Job/skill oriented task analysis
Spatial Analysis Link Tool (SALT)	Link analysis
Task Analysis Workload (TAWL)	Workload analysis
Trigger Analysis	Causal task analysis
WinCrew	A Windows based workload and tasks analysis tool

3.1.4 Staffing and Qualifications

The objective of a staffing and qualifications review is to verify that the applicant has systematically analyzed the number and qualifications of personnel needed to perform human roles and responsibilities and has demonstrated a thorough understanding of task and regulatory requirements. The key aspects to consider in the review include job definition, identification of the skills and abilities required to perform the jobs, shift staffing complements, and effects of shift durations and schedules.

These considerations are typically driven by the task analysis. The task analysis defines what must be done, when it should be done, and what skills and abilities are required. The military has created an entire class of tools for doing these types of analyses, and typically refer to the analyses as manpower and personnel analysis. Training needs, or the identification of training gaps based on skill needs and personnel characteristics, are also often included along with these analyses.

New M&Ts to address staffing and qualifications are listed in Table 3-7.

Table 3-7 Staffing and Qualifications Methods and Tools

Method/Tool	Key Features
Command, Control & Communication - Techniques for Reliable Assessment of Concept Execution (C3TRACE)	Manpower and personnel in team communications
Complex Cognitive Assessment Battery (CCAB)	Cognitive abilities definition
Fatigue Avoidance Scheduling Tool (FAST)	Fatigue avoidance scheduling
Improved Performance Research Integration Tool (IMPRINT)	Army manpower and personnel
Integrated Simulation Manpower Analysis Tool (ISMAT)	Navy manpower and personnel
Job Assessment Software System (JASS)	Job definition
Multiple Aspect Based Task Analysis (MABTA)	Group work analysis
Plant-human Review and Effectiveness Decision Tool (PHRED)	Nuclear manpower and personnel Based on IMPRINT
Ship System Human Systems Integration for Affordability and Performance Engineering (ShipShape)	Navy manpower and personnel
SkillsNet	Skills and abilities definition
WinCrew	Crew workload analysis

3.1.5 Human-system Interface Design

The objective of an HSI design review is to verify that the applicant's HSI design process appropriately translates function and task requirements into the detailed design of alarms, displays, controls, and other aspects of the HSI through the systematic application of HFE principles and criteria.

Emerging HSI design and evaluation technologies can be divided into three broad classes. The first are tools that focus on rendering the operator and the interface in three-dimensional space.

These tools are typically tied to a computer-aided design (CAD) environment. They typically focus on evaluations of HSI visibility of HSIs, reach to controls, and fit using anthropometric models of people of different sizes.

The second class of tool includes integrated design and evaluation criteria and guidance. The criteria and guidance are typically drawn from existing industry standards such as the military standards or NUREG-0700. These kinds of tools are often integrated with tools from the other two classes.

The third class of tool uses human performance modeling to drive HSI design and evaluation. The modeling may be done at the task level, or may involve representing the operator's cognitive processes and detailed actions performed to accomplish the task. They also sometimes include modeling of people with different capabilities (e.g., vision, reaction times, or training) or under different types of stressors (e.g., fatigue, noise, heat, or wearing protective clothing).

New HSI design M&Ts are listed in Table 3-8.

Table 3-8 Human-System Interface Design Methods and Tools

Method/Tool	Key Features
The Adaptive Cognition of Thought Rational (ACTR)	Cognitive modeling tool
Crew Station Design Tool (CSDT)	CAD, guidance, and modeling tool
Computer Aided Systems Human Engineering Performance Visualization System (CASHE-PVS)	Guidance tool
digital enterprise lean manufacturing interactive application (DELMIA) Human	CAD tool
Engineering Control Analysis Tool (ECAT)	Modeling tool
Ecological Interface Design (EID)	Interface design method
Executive Process Interactive Control (EPIC)	Cognitive modeling tool
Envision/Ergo	CAD tool
ErgoMaster	CAD tool
Human Factors Engineering Analysis Tool (HFEAT)	Guidance tool
Interactive Cognitive Subsystems to Cognitive Task Analysis (ICSCTA)	Cognitive modeling tool
Integrated Performance Modeling Environment (IPME)	Modeling tool
Jack	CAD tool
ManneQuinBE	CAD tool
ManMachine Integration Design and Analysis Systems (MIDAS)	Modeling tool
Multimodal Interface Design Advisor (MIDA)	Guidance and modeling tool
Rapid Prototyping	Emerging design method
Safework Pro	CAD tool
SAMMIE CAD	CAD tool
Soar	Cognitive modeling tool

3.1.6 Procedure Development

The objective of the NRC's review of an applicant's procedure development is to verify that HFE principles and guidance have been applied, along with other design requirements, to develop procedures that are technically accurate, comprehensive, explicit, easy to use, and validated.

New technologies are primarily influencing how and when procedures are delivered and presented more so than how they are developed. A recent trend in procedure development is to develop and provide interactive operational and maintenance procedures on-line as a part of the operator or maintainer interface, such as Interactive Electronic Technical Manuals (IETMs) (DoD, 2006). Procedure-aiding systems are also being developed, such as Procédures Électroniques (PROCEL) which is a generic procedure-aiding system that includes tools to assist in the development of check-lists, electronic reminders, and form-based data collection tools, as well as the more traditional list of steps or activities to carry out. Finally, computerized

maintenance systems offer a new way to develop and disseminate procedures. The tools and methods can be adapted to accommodate operational procedures.

From a procedures verification perspective, tools that are utilized in developing task analyses and the design of the human interfaces can also be applied to the development, validation, and verification of operational procedures. By using simulated or virtual models of the system, its interfaces, and even the operators, the correct procedures can be developed to match the actual plant requirements while the plant is being designed. This can help to ensure that potential procedural problems are identified and corrected prior to implementation and that no hazards will be introduced because of the procedures used to perform operational and maintenance tasks.

Two emerging technologies with potential application to procedures are augmented reality and augmented cognition. Augmented reality produces additional sensory information imposed on the actual environment a person is interacting with. Augmented cognition provides mechanisms for supplementing and supporting human cognitive tasks. Both of these technologies may support designers to model and evaluate procedures and the impact of those procedures on human-system interaction.

Table 3-9 lists the procedures development and review tools. Many of the tools listed in the task analysis, human-system interfaces, and verification and validation sections can also be applied to procedures.

Table 3-9 Procedures Development Methods and Tools

Method/Tool	Key Features
Augmented Cognition	Support or supplement cognitive tasks
Augmented Reality	Projects information onto the environment
Computerized Maintenance Systems (CMS)	Maintenance support
Interactive Electronic Technical Manuals (IETMs)	Procedures integrated into operational system
Knowledge-based Augmented Reality for Maintenance Assistance (KARMA)	Augmented reality procedure tool
Nomad Expert Technician System	Augmented reality tool for automobile technicians
Procedures Electroniques (PROCEL)	Procedure-aiding system

3.1.7 Training Program Development

The objective of a training program development review is to verify that the applicant has a systematic approach for developing a personnel training program, including:

- a systematic analysis of tasks and jobs to be performed
- development of learning objectives derived from an analysis of desired performance following training
- design and implementation of training based on the learning objectives
- evaluation of trainee mastery of the objectives during training

- evaluation and revision of the training based on the performance of trained personnel in the job setting

Table 3-10 lists the primary training delivery technologies.

Table 3-10 Training Delivery Technologies

Method/Tool	Key Features
Collaboration Tools	Synchronous training delivered via the web
Embedded Training	Training delivery within the operational system
On-Line Help	As needed, context sensitive training
Outcome Driven Simulations	On-line training via scenario based role playing
Virtual Environments	Immersive training within a computer generated environment
Web Technologies	Training delivered via the web, typically asynchronous

The M&Ts used for conducting manpower and personnel analysis are also commonly used to identify training needs or gaps where the skill and ability requirements are not fulfilled by the capabilities of the people who are expected to operate or maintain the system. These M&Ts are discussed in the Staffing and Qualifications section.

Another class of training M&s aid in the planning and management of training (see Table 3-11).

Table 3-11 Training Planning and Management Methods and Tools

Method/Tool	Key Features
Applied Cognitive Task Analysis (ACTA)	Training analysis
ADVISOR	Training delivery optimizer
Authoring Instruction Materials (AIM)	Training materials management
Afloat Training, Exercise, and Management System (ATEAMS)	Objective based training management
Navy Training Management and Planning System (NTMPS)	Training planning and management
Tactical Warfare Instructional Support Environment (TacWISE)	Training exercise data collection and analysis

3.1.8 Verification, Validation, and Design Implementation

This section addresses two NUREG-0711 elements: “Human Factors Verification and Validation” and “Design Implementation.” They are addressed together because both are based on similar M&Ts for verification and validation (V&V).

The objective of a V&V review is to verify that:

- the applicant has identified a sample of operational conditions that (1) includes conditions that are representative of the range of events that could be encountered during operation of the plant, (2) reflects the characteristics that are expected to contribute to system performance variation, and (3) considers the safety significance of HSI components. These sample characteristics are best identified through the use of a multidimensional sampling strategy to provide reasonable assurance that variation along important dimensions is included in the V&V evaluations.
- the applicant's HSI inventory and characterization accurately describes HSI displays, controls, and related equipment that are within the defined scope of the HSI design review.
- the applicant has verified that the HSI provides alarms, information, and control capabilities needed for personnel tasks.
- the applicant has verified that the characteristics of the HSI and the environment in which it is used conform to HFE guidelines.
- the applicant has validated the integrated system design (i.e., hardware, software, and personnel elements) using performance-based tests to determine whether it acceptably supports safe operation of the plant.
- the applicant's Human Engineering Discrepancy (HED) evaluation acceptably prioritizes HEDs in terms of their need for improvement and the applicant develops design solutions and a realistic schedule for implementation to address those HEDs selected for correction.

The objective of a design implementation review is to verify that the applicant’s has verified that the as-built design conforms to the verified and validated design that resulted from the HFE design process.

Verification and validation M&Ts allow the assessment of whether designs meet the system and performance requirements established during the design and development cycle, and are correct and complete, and consistent.

Table 3-12 lists a set of tools that support the verification and validation process. Most of these are requirements management, CAD-based tools, or human performance modeling tools that were also identified in the functional requirements and HSI design sections.

Many design conformance tools currently in use are software conformance tools. These tools are noteworthy because plant systems within the nuclear industry are becoming more and more software centric, and conformance of the software code will determine the success of the design implementation. The vast majority of software conformance tools focus on standards compliance. However, the M&Ts listed in the following table are used in quality assurance to test software code for design implementation verification.

It should be noted that simulation modeling tools allow the possibility of exercising important operational scenarios and many critical variations of those scenarios in order to assess operator mental and physical workload and task performance as the system is designed. Verification and validation can be difficult to accomplish using with personnel operating the actual system (or system simulation) because of the enormous number of variations in scenarios that are possible. Modeling has the potential to provide supplemental data.

In addition, there is an emerging set of HFE V&V M&Ts, including virtual reality, augmented reality, and augmented cognition.

Table 3-12 Verification and Validation Methods and Tools

Method/Tool	Key Features
CORE	Requirements management
Control Room Engineering Advanced Toolkit Environment (CREATE)	Virtual environment
DELMIA Human	CAD tool
Dynamic Object Oriented Requirements System (DOORS)	Requirements management
Engineering Control Analysis Tool (ECAT)	Human performance modeling
Ergomaster	CAD tool
Envision/Ergo	CAD tool
Improved Performance Research Integration Tool (IMPRINT)	Human performance modeling
Integrated Performance Modeling Environment (IPME)	Human performance modeling
Integral Requisite Analyzer (IRqAR)	Requirements management
LDRA Design Review	Design conformance tool
ManiquinBE	CAD tool
mCheck	Requirements verification
Plant-human Review and Effectiveness Decision Tool (PHRED)	Human performance modeling
Safework Pro	CAD tool
Safety Critical Application Development Environment (SCADE) Design Verifier	Design conformance tool
SAMMIE CAD	CAD tool
Software Reflexion	Design conformance method

3.1.9 Human Performance Monitoring

The objective of a human performance monitoring review is to verify that the applicant has a process to ensure that no significant safety degradation occurs because of any changes that are made in the plant and to provide adequate assurance that the conclusions that have been drawn from the evaluation remain valid over time.

Capabilities for enabling human performance monitoring are benefiting from the migration of HSI technologies to computer-based systems. Computer-based systems support the unobtrusive monitoring of human actions and may enable the use of "black boxes" for NPPs similar to those used on aircraft. Monitoring technologies for human-computer interaction are used extensively in usability testing and market research, including video monitoring of human-system interaction.

Spyware is commonly thought of as an annoyance that is obtrusive and potentially damaging to computer operations. However, some aspects of spyware, such as keystroke logging or monitoring and cookies can be useful for a more fine-grained assessment of human-system interaction. There are many commercially available products that monitor personnel behavior in relation to their computer activity.

Traditional performance monitoring looks at how personnel perform tasks. While this is useful information, no matter how accurately a person performs a task, if it's the wrong task at the wrong time, system failure can result. New technologies enable human activity detection - detecting, tracking or monitoring a person's activities in real time.

Global Positioning System (GPS) technology, once used only by the military, has become widely used. Put simply, GPS operates on a principle of triangulating distance measurements to determine the location of an object. GPS measures the distances from satellites, therefore relying on satellite imaging for positioning. GPS is highly successful for outdoor localization, but because the composition of indoor environments differs so much from outdoor environments, it is not appropriate for indoor localization. Active sensor beacons, however, utilize wireless technology and can be included on small quarter-sized devices to collect, compute, and communicate information such as the whereabouts of plant personnel. Thus, for example, this technology can make it easy for supervisors to monitor the location of maintenance personnel to verify that the right equipment is being serviced.

Table 3-13 lists M&Ts available for human performance monitoring.

Table 3-13 Human Performance Monitoring Methods and Tools

Method/Tool	Key Features
Computer Vision	Computers monitor performance
iBracelet	Hand movement active sensor beacon
iGlove	Hand and finger movement active sensor beacon
Key Ghost	Spyware
Keystroke Logging	Spyware
Massachusetts Institute of Technology Environmental Sensors (MITes)	Active sensor beacon
Motes	Active sensor beacon
Multimedia Video Task Analysis (MVTA)	Video monitoring
Radio Frequency Identification (RFID)	Active sensor beacon
Smart-Its	Active sensor beacon
Softsecurity	Spyware
Wireless Identification and Sensing Platform (WISP)	Hand movement active sensor beacon

3.2 Major Trends and Their Applicability to NRC Reviews

In the previous section, we identified numerous M&T that can be applied within an HFE program. In this section we identify the major M&T trends that these methods reflect. As noted in Section 2, the trends were identified based upon discussions among the project staff to identify similarities and groupings among the M&Ts identified. No formal evaluation criteria were applied. Based on this effort, the following trends were identified:

- Computer Applications for Performing Traditional Analyses
- Computer-Aided Design
- Integration of HFE Methods and Tools
- Rapid Development Engineering
- Analysis of Cognitive Tasks
- Use of Virtual Environments and Visualizations
- Application of Human Performance Models

Each trend is described below. Note that an individual M&T may reflect more than one trend. In addition, the authors determined the applicability of the trends for NRC safety reviews by the methodology described in Section 2.

3.2.1 Computer Applications for Performing Traditional Analyses

Description

Perhaps reflecting the general evolution to computerization of many aspect of the work environment, computer-based tools are available to support organizing information, conducting HFE analyses (such as requirements development and link analysis), and documenting results.

The Human Factors Engineering Analysis Tool is an example of such an application for using NUREG-0700 guidelines (see Appendix A for a description of this tool).

Application in the Nuclear Industry

Our experience in conducting NRC design certification reviews has shown that applicants already make significant use of tools for these purposes.

Impact on NUREG-0711 Reviews

This M&T trend should have minimal impact on NUREG-0711 reviews. NUREG-0711 review criteria are directed at methodology. Computerization alone does not change the methodology itself. Thus, little impact is expected. In fact, computerization of information actually facilitates the review process because it makes the analyses more traceable and easily audited. In addition, the search capabilities of computer-based tools make information access in support of reviewer needs easier as well.

3.2.2 Computer-aided Design

Description

M&Ts are increasingly available that not only provide computer support for HFE analyses, they provide "intelligent" input to designers. An example is the Human Centered Design Advisor that provides recommendations to designers for meeting HFE guidelines (see Appendix A for a description of this tool).

Application in the Nuclear Industry

We have not found instances of the use of such tools in the commercial nuclear industry.

Impact on NUREG-0711 Reviews

M&Ts of this type could have an impact on NUREG-0711 reviews. Reviewers would have to determine the basis and validity of the "intelligence" being provide by the M&T to the designer. In addition, reviewers would have to verify that the recommendations being made by the M&T are appropriate to the current application. Guidance on this type of assessment is not currently available and would be needed.

3.2.3 Integration of HFE Methods and Tools

Description

In the past HFE professionals had separate tools to do activities such as function analysis and task analysis. Increasingly, M&Ts are available that integrate many HFE activities into a single application. In fact, many of the tools identified can be used to address multiple aspects of the design process. An example is the Crew Station Design Tool provides a set of tools for integrating task analysis and HSI design. See Appendix A for a description of this tool.

Application in the Nuclear Industry

Our experience in conducting NRC design certification reviews has shown some use of integrated applications, although such approaches do not seem pervasive.

Impact on NUREG-0711 Reviews

The use of integrated tools should not pose challenges for NRC reviewers provided the approaches and information sources used for each type of analysis is accessible for staff review.

3.2.4 Rapid Development Engineering

Description

As was noted in Section 3.1.1, systems engineering models in general are evolving to produce results more quickly and at lower cost. This trend is clearly seen in HFE M&Ts as well. Methods such as rapid prototyping enable design to become much more iterative and fast paced. Rapid prototyping is often performed with system users as a means of soliciting feedback, making HSI modifications, and repeating the cycle until the design is completed. Thus designs are developed more rapidly, at less cost, through the use of iterative methods, incorporating user input and feedback. Some of the same tools can also be used to provide operations personnel with tools to change HSIs to meet their needs.

Application in the Nuclear Industry

We have not found instances of the use of such tools in the commercial nuclear industry.

Impact on NUREG-0711 Reviews

The overall impact of rapid development engineering M&Ts is difficult to assess at this point. Since these techniques do not seem to be used currently, a final assessment should await a determination of when and how the techniques are applied.

Some of the tradeoffs to consider include the following. On one hand, traditional approaches to HFE design rely on performing careful information requirements analysis, applying HFE guidelines, developing concept designs, conducting evaluations, developing detailed designs, and verifying/validating the design. On the other hand, rapid development engineering M&Ts may abbreviate or eliminate some aspects of this more traditional approach. As the NRC review process is modeled on the traditional approach and tracks these processes, aspects of the review process may not be able to be applied. Further, a rapid engineering approach may introduce new processes that are not currently addressed in NUREG-0711.

As noted above, some of the same tools can be used by operations personnel to change HSIs to suit their needs, thus bypassing the more time-consuming traditional engineering change process. The use of such tools has a potential safety impact in that operator changes can potentially introduce errors into the HSIs.

3.2.5 Analysis of Cognitive Tasks

Description

Digital technology has changed plant I&C systems to provide much more information processing and automation than was possible previously. In addition, the same technology has led to computer-based interfaces that provide much more operator support than was possible in control rooms of the past. The operator's role is increasingly moving to that of a supervisory controller who oversees plant automation, intelligent agents, and operator support systems, rather than performing manual control tasks. The shift in the operator's role to supervisory control in complex systems such as nuclear power plants has led to an increased emphasis on the importance of analyzing cognitive tasks such as detection, situation assessment, and decision making. Traditional task analysis approaches do not accommodate cognitive tasks very well because the focus is on physical tasks and the actions necessary to perform them. A new suite of cognitive task analysis and knowledge engineering methodologies has emerged to fill this need. Examples include Cognitive Work Analysis and Cognitive System Design.

Application in the Nuclear Industry

M&Ts included in this trend are used by the commercial nuclear industry. For example, Westinghouse's function based task analysis for the AP600 and AP1000 uses an adaptation of Rasmussen's decision making model (Westinghouse, 1996).

Impact on NUREG-0711 Reviews

The use of these M&Ts is generally consistent with the top-down approach underlying the guidance in NUREG-0711 and the review criteria for both function analysis and task analysis necessitate that some type of cognitive analysis be performed. However, there may be challenges to reviewers in determining that the specific methods that are used are appropriate for the analysis of NPP personnel tasks. Unlike more traditional methods, such as Operational Sequence Analysis, which have been used extensively in the industry, most cognitive analysis methods are new and have not been used extensively. Therefore, reviewers will have to determine their comprehensiveness and appropriateness for NPP applications. Guidance to support this determination may be useful.

3.2.6 Use of Interactive Virtual Environments and Visualizations

Description

Techniques such as virtual reality are being used to create models to support visualization and interaction with the physical environment and physical phenomena by designers and researchers. These models support design and evaluation as a supplement to, or replacement of, static computer models, physical mockups, and simulators. Virtual reality models enable early visualization and assessment of the hardware environments. Members of the design or operations team can interact with the models in various ways. This allows for early human-in-the-loop testing and design revision. For example, virtual reality can be used to interactively evaluate control room layout issues with members of the design team and operations personnel.

Application in the Nuclear Industry

The nuclear industry is making extensive use of virtual environments and visualizations for a broad spectrum of activities. Virtual reality (VR) was used to evaluate control room layout issues during the Oskarsham control room modernization project in Sweden. The evaluations were conducted using VR facilities at the Halden Reactor Project in Norway. While this represents a fairly straight forward application of VR, many other applications are discussed in the literature. Examples of nuclear industry applications include:

- Full-scale immersive virtual mockups of spaces inside the Westinghouse AP1000 were used to understand the technology's potential contributions to design, construction, and operation of future nuclear power plants. Provides capability to virtually perform human-in-the-loop task simulations which enable improved insight into arrangement, manufacturing, and operational issues (Vaughn et al., 2004).
- 2.5-D and 3-D visualization technology can be used to evaluate the design of a nuclear power plant control room upgrade. Evaluators viewed and interacted with the control room virtual model. The Halden CREATE Verification Tool was also used to evaluate features of the virtual control room using NUREG-0700 (Hanes & Naser, 2006) (see also Droivoldsmo et al., 2000).
- The application of visualization technology to improve human situation awareness, problem solving, and decision-making in nuclear power generating stations and associated utility support organizations (Hanes, 2004).
- The application of VR for the purpose of radiation exposure management (Hajek, 2004) (see also Louka et al., 2008; Nystad, 2005; Nystad & Sebok, 2005).

EPRI has prepared guidance for utilities to support the use of VR and visualization technology (Hanes, 2006).

Impact on NUREG-0711 Reviews

As can be seen from the examples above, the application of M&Ts for creating models to support visualization and interaction with the physical environment and physical phenomena has very broad application. Some of the applications involve fairly simple computer modeling of the physical environment, such as a control room. Others involve the integration of multiple models of physical phenomena, such as modeling radiation fields in hot areas of a plant.

As the applications are diverse, the extent to which the use of such models impact NUREG-0711 reviews range as well. Applications such as the evaluation of physical control room layout should pose little difficulty. However, once more interactive features are used, questions as to the validity of the response of the VR models arise. Currently, no guidance is available to the NRC reviewer to determine that the models provide a valid representation of the proposed design.

Even more challenging are integrative models, such as modeling radiation fields together with the physical layout of an area in the plant in order to assess maintenance personnel performance. A license application or amendment request based on the use of this technology would be difficult to evaluate at the present time. Additional guidance may be useful.

Another consideration is the use of these M&Ts to automatically perform evaluations such as NUREG-0711 reviews. NRC reviewers will have to determine precisely how the application is using the guidelines and what VR parameters are used in the evaluation. Thus, the use of VR will have an impact on NUREG-0711 reviews.

3.2.7 Application of Human Performance Models

Description

There is a significant push in the human factors community to develop human performance models that can be applied to design and evaluation projects. One driving force behind this push is limited availability of operators (this is an issue for most complex system domains, not just commercial nuclear). In addition, collecting data with operators often means using full-scope simulators. Such studies are very expensive, time consuming, and provide limited data sets. Thus, as a supplement to or replacement of data collection with actual users, HFE professionals have been developing human performance models. Such models simulate various aspects of individual and team performance. Task network modeling and discrete event simulation are examples of human performance models.

Application in the Nuclear Industry

The NRC and the nuclear industry have developed and used human performance models. One of the primary applications has been to investigate plant staffing issues. The NRC has conducted research on staffing alternatives that used task network modeling techniques (Laughery & Persensky, 1994; Laughery, Plott, Engh, & Scott-Nash, 1996; Laughery, Plott, & Persenksy, 1996; Lawless, Laughery, & Persensky, 1995). The NRC has also developed a modeling tool called PHRED tool to support staff reviews (see Appendix A for additional information on PHRED). Partly as a result of these encouraging results, modeling was identified as a means of evaluating applications to reduce the minimum numbers of licensed staff required in the control room below those identified in10 CFR 50.54(m) (Plott, Engh, & Barnes, 2004; Persensky, Szabo, Plott, Engh & Barnes, 2005).

Other applications have included the prediction of operator response to disturbance scenarios (Yow et al., 2005) and the prediction of situation awareness (Walters & Yow, 2000).

Human performance modeling is currently being used in the design of the Pebble Bed Modular Reactor as an extension to task analysis to evaluate event timing and action, error rate, and the effects of performance shaping factors and workload (Hugo, 2006).

Thus, human performance modeling M&Ts can be used in the nuclear industry for a wide variety of applications and are likely to play even larger roles in the future (as they currently are in other application domains such as DoD and aviation).

Impact on NUREG-0711 Reviews

Using human performance models has significant impacts on NUREG-0711 design reviews. As the models can be applied throughout the analysis, design, and evaluation process their impact is pervasive. Further, unlike many of the M&T trends above that are used by applicants and whose results are evaluated by regulatory staff, human performance models may be used by regulatory staff to evaluate design submittals.

To be used in a regulatory review, whether by the NRC staff or as part of an applicant submittal, the validity of the modeling and its results will have to be assured. The types of questions that should be addressed include:

- What type and amount of information and data are needed to build models?
- What types of models are appropriate to what situations and how can inappropriate use be identified?
- Are the models of sufficient fidelity for use in regulatory evaluations?
- How are models validated?
- What is the value added with modeling, e.g., what can be accomplished with the models that extends beyond what can be practically accomplished with actual data collection?
- What is the relative role of results from actual human trials and results produced by models?

Guidance may be useful to support the NRC staff in reviewing the use of human performance models.

3.3 Conclusions

We identified seven trends in the M&Ts identified in our survey. The M&Ts representing each trend were evaluated by the project team with respect whether they are used in the nuclear industry and whether they might impact the staff's ability to conduct reviews. The results are summarized in Table 3-15.

As per the decision logic presented in Section 2, there may be no immediate need to consider M&Ts trends that are not currently used in the nuclear industry or that have no impact on HFE reviews. Four of the M&T trends fall into this category: Computer Applications for Performing Traditional Analyses, Computer-Aided Design, Integration of HFE Methods and Tools, and Rapid Development Engineering.

The NRC may consider developing guidance for reviewing applicant submittals containing M&Ts in the following trends: Analysis of Cognitive Tasks, Use of Virtual Environments and Visualizations, and Application of Human Performance Models.

Table 3-14 Results Summary

M&T Trend	Use in Nuclear Industry	Impact on NRC HFE Reviews
Computer Applications for Performing Traditional Analyses	Yes	No
Computer-Aided Design	No	Yes
Integration of HFE Methods and Tools	Yes	No
Rapid Development Engineering	No	To be determined
Analysis of Cognitive Tasks	Yes	Yes
Use of Virtual Environments and Visualizations	Yes	Yes
Application of Human Performance Models	Yes	Yes

4 SUMMARY

The NRC's HFE review of applicant submittals for new plants and for changes to existing plants includes the evaluation of the M&Ts used by applicants as part of their HFE program. The technology used to perform HFE activities has been rapidly evolving, reflecting changes in approaches to systems engineering in general. These developments are resulting in a whole new generation of M&Ts are available to support HFE practitioners in the performance of their tasks. As these new M&Ts are adopted for use in the commercial nuclear industry, the NRC staff will need review guidance to determine that they are being appropriately used.

The objectives of this research were to identify the current trends in HFE M&Ts, determine their applicability to NRC safety reviews, and identify topics for which the NRC may need additional design review guidance. We conducted a survey that identified over 100 new HFE M&Ts. The M&Ts were assessed to identify general trends as an aid to guidance development. There are so many individual HFE M&Ts, that it is impractical to develop review criteria for each one. Instead, review criteria can be developed for important trends, resulting in criteria that can be applied to a large number of M&Ts.

Seven trends were identified:

- Computer Applications for Performing Traditional Analyses
- Computer-Aided Design
- Integration of HFE Methods and Tools
- Rapid Development Engineering
- Analysis of Cognitive Tasks
- Use of Virtual Environments and Visualizations
- Application of Human Performance Models

We assessed each trend to determine its applicability to the NRC's review of HFE design processes using NUREG-0711. To perform the assessment we considered (1) whether the nuclear industry is making use of M&Ts for each trend, and (2) whether M&Ts reflecting the trend can be reviewed using the current design review guidance in NUREG-0711. Based on the answers to these questions, we found that M&T trends that are applicable to the commercial nuclear industry and are expected to impact NUREG-0711 reviews may be considered for review guidance development. Three trends fell into this category: Analysis of Cognitive Tasks, Use of Virtual Environments and Visualizations, and Application of Human Performance Models. The other trends do not need to be addressed at this time.

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APPENDIX A

Method and Tool Descriptions

This appendix is intended to give the readers a better understanding of the purpose and functions of the M&Ts discussed. The M&T descriptions were obtained primarily from the source materials identified in the appendix with little to no rewording. Thus, enthusiastic descriptions of the capabilities of individual M&Ts or apparent endorsements reflect the opinions of the authors of the referenced source material and do not reflect the opinions of the authors of this report.

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Method and Tool Descriptions

ACTA (Applied Cognitive Task Analysis)

ACTA is an instructional software tool that is designed to assist practitioners in identifying cognitive skills, or mental demands, that are needed to perform a task. These skills/demands include: critical cues and patterns of cues; assessment, problem solving, and decision-making strategies; why these are difficult for novices; and common novice errors. ACTA provides a means for practitioners to elicit this kind of information and incorporate it into instructional design. ACTA can also be used as a support tool for cognitive engineering and decision-centered design approaches to systems, user interfaces, and training.

Information about Applied Cognitive Task Analysis retrieved December 31, 2007, from:

http://dtica.dtic.mil/ddsm/srch/ddsm83.html
http://decisionmaking.com/approach/ACTA_CD.html

ACT-R

ACT-R is a cognitive architecture that is based on integrated theories of cognition, visual attention, and motor movement. It presents itself as a programming language, but is designed to model and predict human behavior by processing and generating intelligent data.

Users create models which incorporate ACT-R's view of cognition with their own assumptions about a particular task. These assumptions are then validated by comparing the results of people performing the same tasks using traditional measures such as:

- Time to perform the task,
- Accuracy in the task, and
- (more recently), neurological data such as those obtained from Functional Magnetic Resonance Imagine (FMRI), a "brain mapping" technique used to determine which parts of the brain are activated by physical sensation or activity.

One important feature of ACT-R that distinguishes it from other theories in the field is that it allows researchers to collect quantitative measures that can be directly compared with the quantitative measures obtained from human participants.

Information about ACT-R retrieved December 31, 2007, from:

http://act-r.psy.cmu.edu/

ADVISOR

ADVISOR 3.5 is a decision support tool. It analyzes a training course by utilizing a seven step process to recommend the most economical blend of delivery methods (including instructor-led, print, tapes, computer-based training, Web-based training, electronic performance support tools, audio/computer/video conferencing, Internet, and others) to meet the training needs of the instructor and facility. The first step to the analysis is to list instructional goals, and then group them into instructional modules. Then for each instructional module, the effectiveness of plausible options is evaluated, the scheduling is estimated, costs are computed, and delivery

options are rated. The final steps are to assess risk and identify and compute hidden costs, and finally to determine the appropriate blend of delivery options.

Information about Advisor 3.5 retrieved December 31, 2007, from:

http://www.bnhexpertsoft.com/

AIM (Authoring Instructional Materials)

Authoring Instructional Materials (AIM) is a government-managed system used by the Navy and other agencies to develop, update, manage, and integrate training content. AIM is a training content authoring and management environment that utilizes a combination of commercial and government software tools. Training content is linked in a relational database that is integrated with other training systems that are used to automate maintenance and updating. It ensures uniform formatting and compliance of all required output products, in any form, from paper to web. AIM provides highly efficient design, development, surveillance, maintenance, and production of training/educational materials.

Information about AIM retrieved December 31, 2007, from:

http://ete.fedsun.navy.mil

Analyst Pro

Analyst Pro is a tool for requirements management, tracing and analysis. Among its features, it uses a hierarchical outline structure to build UML Use Cases for requirements specifications. This structure provides the user with the ability to link models and documents to the requirements which will allow for automatic change history tracking. In addition, a Traceability Matrix provides the designer with the ability to conduct impact analysis and product testing.

Analyst Pro can be used for many software, systems and product development projects and can be used with a variety of systems design approaches.

Information about Analyst Pro retrieved December 31, 2007, from:

Goda Software, Inc., http://www.analysttool.com/
Volere (2005). Requirements Tools. http://www.volere.co.uk/tools.htm .

ATEAMS (Afloat Training, Exercise, and Management System)

Afloat Training, Exercise, and Management System (ATEAMS) is a fleet's initiative to provide an automated process to manage Objective Based Training (OBT) that supports conducting training based on pre-defined objectives that are both measurable and traceable. Commands can use several paths for selecting objectives to rapidly identify the desired training focus. In addition, it provides a simplified means to develop training scenarios that are traceable to selected objectives, as well as providing standardized methods to measure team and individual performance. The results of ATEAMS related exercises support Battle Force Tactical Training Debrief (a training tool used to provide rapid feedback on trainee performance) and provide objective-based feedback both to the chain of command and to the Navy training facilities supporting fleet readiness.

Information about ATEAMS retrieved December 31, 2007 from:

https://www.spider.hpc.navy.mil/index.cfm?RID=APP_OT_1000082

Augmented Cognition

The phrase augmented cognition (AugCog) was first used in 2000 during deliberations of a DARPA working group. The term was used at that time to describe research exploring opportunities for developing principles and computational systems that support and extend human cognition by taking into explicit consideration well-characterized limitations in human cognition, spanning attention, memory, problem solving, and decision making. Low-hanging augmented cognition fruit include methods for managing interruption and recovery, assisting with multitasking, enhancing bandwidth via exploiting multiple channels, providing reminders or assistance at the right time, and addressing biases in judgment. AugCog support will be increasingly critical to designers of NPPs as NPPs become more automated and operators assume the role of supervisory control. AugCog systems have already been implemented in some data rich environments as described below.

The goals of augmented cognition are to:

- Enhance learning and memory via reminder systems & methods
- Automate specific aspects of problem solving & filtering
- Modulate / triage communications
- Develop new visualizations and other information rendering to increase the rate of "concept attainment" by the human in the system --- raising the effective human-computer bandwidth

Augmented cognition designs and methods attempt to provide operator support to overcome characteristic human limitations in cognition.

Information about Augmented Cognition retrieved December 31, 2007, from:

http://www.darpa.mil/ipto/briefings/dds_darpatech2002_speech.pdf
http://research.microsoft.com/~horvitz/acog/ehorvitz_overview_nov11.ppt#2490,8,Augmented Cognition Efforts
http://research.microsoft.com/~horvitz/speechcontext.pdf
http://www.megaputer.com/products/wa/architecture.php3
http://www.inquira.com/

Augmented Reality

Augmented reality (AR) is a potential procedure-development tool that will provide real-time procedure guidance. Basically, AR superimposes graphics and other sense enhancers over a user's real world environment. These enhancements are dynamic and occur in real time so as the user adjusts or moves, the enhancements also adjust, just as they would in the real world. Augmented reality is not a virtual reality, in the sense that it merely embeds or augments the real world in order to optimize human performance.

AR is still in the research and development stage in many universities and high tech laboratories. It is also being explored by the military for troop enhancement. The Defense Advanced Research Projects Agency (DARPA) and the Office of Naval Research (ONR) have both funded research to explore the use of AR to enhance troop situation awareness.

The goal of AR is to integrate the three components needed:

- Head-mounted display
- Tracking system
- Mobile computing power

Integrating these components into one unit produces a belt worn device that will transmit information about the user's surroundings to a head-mounted system that closely resembles a pair of goggles. All transmissions are performed wirelessly, providing greater mobility for the human.

Information about Augmented Reality was retrieved on December 31, 2007 from:

http://www.sportvision.com/
http://www.hitl.washington.edu/projects/vrd/
http://www.hitl. washington.edu/publications/p-93-2/
http://www.cs.nps.navy.mil/people/faculty/capps/4473/projects/fiambolis/vrd/vrd_full.html#WhoDeals

Business Process Modeling

Many design methods look at the system in terms of its data flow, its relationships, and its uses. What was not considered by these methods was business processes. Business processes are the activities required to achieve the business goals. Business processes form functional requirements by asking:

- Why - the business requirement
- What - what must be accomplished to achieve the goal
- Who - who is responsible for those actions
- Where - where the actions are performed
- When - the timeframes associated with the actions

Business Process Modeling is a method which answers the 5 "W" questions listed above. The three main objectives are to (1) create a common understanding of business processes, (2) Gain agreement among stakeholders in how business processes are to be implemented, and (3) Design a new process that provides enough detail for effective implementation. (McGuire, 2004)

Business Process Modeling is also known as workflow modeling, because it is used to identify tasks and the resources associated with those tasks. It is generally used to align the goals and objectives of an organization with the tasks that are performed by the various stakeholders whether human or machine. This method does not consider the abstract cognitive human behaviors in the requirements specification and analysis process. Instead, humans and machines and the respective tasks they perform are considered as components in the system as a whole, to meet the objectives of the organization. While it is not a traditional human factors

method, it is widely used in requirements engineering and may be a method that the Human Factors Engineering industry begins to adopt.

A common language used in Business Process Modeling is the Business Process Execution Language (BPEL). BPEL is an XML based language developed to enable task sharing across distributed platforms or systems.

Information about Business Process Modeling retrieved December 31, 2007, from:

McGuire, K., (2004). Business Process Modeling. Appropriate Approach Pty Ltd. www.appropriateapproach.com . Last updated 2004.

C3TRACE (Command, Control, and Communication Techniques for Reliable Assessment of Concept Execution)

C3TRACE is a modeling environment that can be used to evaluate the effects of different personnel architectures and information technology on system and human performance. It includes a graphical user interface for easy configuration of organizations, personnel and their tasks, a communications and scenario generation module, a discrete event simulation engine (Micro Saint Sharp), and data analysis module.

Within C3TRACE, any organization, the people assigned to that organization, and the tasks and functions they will perform can be easily represented. Communications within and outside of the organization can be represented as information (voice, face-to-face, digital, written) that will be considered in decision-making. Organizations and their personnel can be evaluated with "what-ifs" to see the impact of the different configurations on C2 without the need for a live exercise or experiment. Important performance considerations for each organization include task times, information quality on which tactical decisions can be based, and workload levels.

For more information contact:

Alion Science and Technology
4949 Pearl E. Circle
Boulder, CO 80301

See also:

Yerace, G. and Bowman, E. Command and Control in Complex and Urban Terrain: Human Performance Modeling Decision Making and Cognitive Analysis. Presented at the 10th International Command and Control Research and Technology Symposium, June 2005. Retrieved from http://www.dodccrp.org/events/2005/10th/CD/papers/038.pdf

CARE

CARE (Computer Aided Requirements Engineering) is a tool for generating, structuring and managing requirements on complex software systems. It supports a methodical and established proceeding in large and distributed project groups. CARE benefits from the advantages of the Lotus Notes groupware platform. CARE does not only offer a distinctive security concept, but also a flexible role- and state model. Due to its numerous configuration possibilities, CARE can be adapted to any project and basic condition. In order to provide a large number of users with

the benefits of a Requirements Engineering and Management tool in the simplest way, CARE can additionally be used through a browser. CARE also offers a defined process for Requirements Engineering and Management by consequently realizing the SOPHIST's method of Object Engineering. This procedure unites linguistic methods, acceptance criteria, object-oriented analysis and prototyping which, as a whole, portray a practically acquired and successful process in one flexible tool.

Information about CARE retrieved December 31, 2007, from:

Sophist Group, http://www.sophist.de
Volere (2005). Requirements Tools. http://www.volere.co.uk/tools.htm . Last updated November 2005.

Case Based Reasoning (CBR)

Case Based Reasoning (CBR) is a method that favors learning from experience. It is based upon two tenets: solutions for similar prior problems can be a starting point for current problems; and, problems tend to recur. The CBR approach is a 4-step process that looks for previous examples within a knowledge repository that are similar to the current problem or issue presented by the user. CBR tools are similar to search engines on the Internet, in that they match key words or strings to key words or strings within the database. However, CBR tools are more adaptive, and the burden of the learning or remembering is placed upon the machine, rather than the user. An explanation of the steps involved in the CBR process demonstrates this.

The four steps taken in the CBR process are as follows:

- Retrieve - After being presented with the search key, the system retrieves from memory the case or cases which match the search. The case will consist of the problem, the solution, and annotations about how the solution was derived.
- Reuse - The solution from the previous case that best fits is mapped to the current problem. In some cases, the fit may not be perfect, and the user will adapt the solution to fit the new instance.
- Revise - The new solution is tested in a real-world application (or simulation), and any revisions to be made are entered into the system.
- Retain - After successfully making changes, the revised case is saved in memory as a new case for future use.

Learning for CBR tools is driven both by successes and failures. For success driven cases, solutions are stored as useful tools for collecting data about "best practices". For failure driven cases, solutions that fail or solutions that differ from predictions are saved for future reuse to avoid future mistakes.

Case Based Reasoning is most widely used in call centers and help desk applications where immediate access to historical performance is critical to providing customer support.

For more information see:

Leake, D., (2000). CBR in Context: The Present & Future. Case Based Reasoning: Experience Lessons & Future Directions, AAAI Press/MIT Press.

CASHE: PVS (Computer Aided Systems Human Engineering: Performance Visualization System) developed by HSIAC (Human Systems Information Analysis Center)

CASHE: PVS was developed by the Crew Systems Ergonomics Information Analysis Center (CSERIAC) as an ergonomics design tool. It includes a database of ergonomics data and models stored in multi-media formats. In addition, CASHE:PVS includes a hypertext version of the Perception and Performance Prototyper (P3) which is used to assist users in interpreting and applying ergonomics to specific problems.

For more information see:

Fifty Years of Human Engineering: History and Cumulative Bibliography of the Fitts Human Engineering Division., edited by Rebecca J. Gree, Herschel C. Self, Tanya S. Ellifritt., Retrieved December 31, 2007, from http://www.hec.afrl.af.mil/Publications/intro.pdf .

CCAB (Complex Cognitive Assessment Battery)

CCAB contains nine tests of higher cognitive functions. The tests are: Tower Puzzle, Mark Numbers, Numbers and Words, Information Purchase, Route Planning, and Missing Items. The PC-based software features the capability of customized test configurations, menu-driven software, repeated measures, variable levels of difficulty, and automated scoring and reporting. CCAB is written in the C programming language.

CCAB is a performance evaluation tool which allows users to test the effects of various stressors on cognitive performance (Tauson, etal., 1995). It is listed in the United Kingdom's Ministry of Defence Standard 00-25 as a tool for conducting workload analysis (Ministry of Defense, 2004). In addition, CCAB is useful in task analysis, and is considered a standard tool for conducting cognitive task analysis in air traffic management by the European Organization for the Safety of Air Navigation (Kelly et al., 2000).

The appropriate uses of CCAB vary with the user. For the military, CCAB can test the effects of battlefield stressors on cognitive performance. It also can test for differences in Military Occupational Specialty (MOS) requirements. For the academic, the repeated measures feature makes the CCAB ideal for drug or sleep-deprivation research. The CCAB also can be used for the basic investigation of higher cognitive functioning. For users in industry, CCAB's flexibility permits configuration of specialized batteries for jobs with different cognitive profiles. CCAB can be used in the health field as an aid for neuropsychological testing of higher cognitive functions.

Information about CCAB retrieved December 31, 2007, from:

http://www.dtic.mil/matris/ddsm/srch/ddsm0009.html
http://www.dstan.mod.uk/data/00/025/15000100.pdf

See also:

TAUSON, R. A., N. W. DOSS, ET AL. (1995). The Effect of Vehicle Noise and Vibration (Caused by Moving Operations) on Cognitive performance in the Command and Control Vehicle. Aberdeen Proving Ground, MD. USA, US Army Research Laboratory: 65.

Kelly, C., Enterkin, P., and Goillau, P. Human Factors Integration in Future ATM Systems - Methods and Tools., Released August 8, 2000. Retrieved online from http://www.eurocontrol.be/humanfactors/gallery/content/public/docs/DELIVERABLES/HF23%20(HRS-HSP-003-REP-03)%20Released.pdf

CMS (Computerized Maintenance Systems)

Computerized Maintenance Systems are systems designed to evaluate standard procedures in a maintenance system to ensure that the activities being performed are fully aligned with the goals of the organization, while keeping costs at a minimum and safety at a maximum. One such tool that also offers the ability to create standard operating procedures and then allocate those procedures to various resources is Maintimizer offered by Ashcom Technologies. Future versions of Maintimizer promise the ability to customize the CMS to fit any scenario, making it a viable tool for procedure evaluation and development.

Information about CMS retrieved December 31, 2007 from:

Ashcom Technologies, http://www.ashcomtech.com/html/maintimizertourpreventive.html

Cognitive Archeology

Most methods acknowledge the importance of artifacts, context, and observation in understanding physical activities during task analysis. According to Spillers (2003), these same aspects can also shed light on cognitive activities. He calls understanding these unseen activities 'cognitive archeology'. In the context of task analysis, cognitive archeology "involves the elicitation, interception and capture of the cognitive activities that a user finds beneficial and essential to successfully complete a task." (Spillers) Just as traditional archeology centers on the study of artifacts, so does cognitive archeology. These artifacts are those elements whose function is to ensure task success. Examples include memory aides, changes in temperature or sound, and symbols such as check marks, or calendar symbols. These can also be physical artifacts such as post-it notes, logs, or calculators.

Information about cognitive archeology retrieved December 31, 2007, from: http://www.experiencedynamics.com/articles/published_works/index.php/

See also:

Spillers, F. (2003): Task Analysis Through Cognitive Archeology, The Handbook of Task Analysis for HCI, Eds. Laurence Erlbaum Associates, D. Diaper and N. Stanton (Eds.), in press Sept. 2003

Renfew, C. (1994). The Ancient Mind: Elements of Cognitive Archeology. Cambridge: Cambridge University Press.

Cognitive Systems Design

"A Cognitive System is one that utilizes psychologically plausible computational representations of human cognitive processes as a basis for system designs that seek to engage the underlying mechanisms of human cognition and augment the cognitive capacities of human users, not unlike a "cognitive prosthesis."

The above definition was taken directly from the Sandia National Laboratories Cognitive Systems Program website (http://www.sandia.gov/cog.systems/Index.html). This organization of Sandia National Labs is focused on transforming machines to more accurately reflect their human counterparts so that human - machine interaction is as close to human-human interaction as possible. The foundation for Sandia's Cognitive Systems research and projects is human emulation in which a synthetic human or intelligent machine is equipped with "cognitive models that operate in real-time and in coordination with other simulation or system control processes". (Sandia website)

Information about cognitive systems design retrieved December 31, 2007, from:

http://www.sandia.gov/cog.systems/cognitive_workshop/
http://www.unm.edu/cognitive_systems/

See also:

Rasmussen, J., Pejtersen, A., Goodstein (1994). Cognitive Systems Engineering. John Wiley & Sons, Inc. New York, New York.

Cognitive Work Analysis

Cognitive Work Analysis (CWA) is defined as a "systems-based approach to the analysis, design, and evaluation of human-computer interactive systems that unifies psychological and technical considerations - in other words, cognition and the engineered 'ecology' in which cognition takes place." (Sanderson, 1998) CWA differs form traditional Human Computer Interaction (HCI) techniques for several reasons:

- CWA views behaviors as being influenced by the attributes of the environment in which the work is being performed as well as the attributes of the work and the individual attributes of the person performing the work.
- CWA utilizes psychological theories but the core foundation is centered on the system as a whole (to include the humans interacting within the system)
- CWA models the ecology in which work is performed to set the bounding constraints for the system, and offer potential actions.
- CWA does not dictate how work should be performed, and it doesn't describe how work is currently being performed within a system. Instead it identifies potential designs for the interface and possible areas for optimization within that interface.

In focusing on the system or the work performed within the system, CWA recognizes that the constraints of considering all of the possible attributes of the human are far greater than the

constraints of considering all of the possible attributes of the system and work performed within the system.

For more information see:

Sanderson, P. (1998). Cognitive work analysis and the analysis, design, and evaluation of human-computer interactive systems. Paper presented at the Proceedings 1998 Australasian Computer Human Interaction Conference. OzCHI'98, 30 November-4 December, 1998, Adelaide, SA, Australia, p. 220-227.

Collaboration Tools

Advancing technologies and computing systems have facilitated the formation of geographically distributed teams. Such teams require methods of collaboration that allow each participant to provide input as if everyone were in the same meeting room. These methods are invaluable to program development, knowledge sharing and management, and training development.

The following tables provide the lists of collaboration methods, technologies and tools compiled by the Systems Software Consortium. These lists were taken directly from their web site at http://www.systemsandsoftware.org/ssci/default.asp . Additional information on the tools can be found there.

Table A1 Collaboration Methods

Method or Technology	Short Description
Application Sharing	Allows two or more people to jointly view and use an application running on a remote computer
Audioconferencing	Allows two or more people to communicate in real time via audio on a personal computer or telephone
Blog	A "blog", or "web log" is a publication tool for creating frequently updated web content that encourages personal communication and collaboration.
Data Conferencing	Allows two or more people to share application data in real time via a personal computer
Discussion Forums	Online resources that allow users to post messages and reply to other postings, thereby creating threaded discussions
Distributed Document Management	A collection of features that may include those that assist with document creation, review and approval, versioning and archiving, publishing, and related coordination and routing
Distributed Project Management	A collection of features that assist with workforce management and project coordination. May include assigning tasks, due dates, and resources, and tracking progress against milestones
Distributed Software Development	A collection of features that assist with software development. May include schedule and task management, source code repositories and configuration management, bug tracking, communication tools, etc.

Method or Technology	Short Description
Distributed Version Control	A collection of features that assist with coordinating and controlling changes to software source code, such as versioning and archiving, check-in/check-out, merging, and release packaging.
Email	Messages sent from one computer user to another, usually over the Internet, which can be queued for later reading and retrieval. Email is the most pervasive collaboration technology today.
File Sharing	Provides a common area for networked computer users to transfer files to each other
Group Calendaring and Scheduling	Allows two or more people to share calendar data and jointly schedule meetings
Instant Messaging	Allows two or more people to communicate in real time by exchanging short text-based messages.
Intranet	An internal network that allows network clients to access common files and applications
Presence Detection	A key feature of instant messaging and other applications. Provides users with the real-time online status of other computer users.
Remote Desktop Access	Allows a computer user to remotely control all aspects of a computer across the Internet
Shared Clipboard	Provides a common area for computer users to transfer portions of files to other computer users. Uses a "cut and paste" method.
Videoconferencing	Allows two or more people to communicate in real time via video on a personal computer
Virtual Workspace	A collection of features that enable a remote workgroup to maintain a common work area in which they can share files and work together virtually.
Webcasting	Using the web to deliver live video presentations to numerous viewers at the same time. Archived versions of the broadcast frequently are made available.
Whiteboarding	Allows two or more people to collaborate by writing, drawing, or pasting images and text into a shared virtual area. Results of each participant's actions can be seen by all other participants.

Table A2 provides a comprehensive list of collaboration tools and their vendors.

Table A2 Collaboration Tools

Tool Name & Version	Vendor Name
Groove Workspace 2.5	Groove Networks, Inc
Citrix MetaFrame Access Suite Varies with operating system	Citrix Systems, Inc.
ClearCase 2003.06	IBM Corporation
Click to Meet 3.0	First Virtual Communications, Inc.
CodeBeamer 3.0	Intland Software
CVS - Concurrent Versions Systems 1.11.6	(open source software)
DocuShare 3.1	Xerox
eRoom Real Time Services	Documentum, Inc.
Exchange 2000 Conferencing Server	Microsoft Corporation
Exchange 2000 server	Microsoft Corporation
Flypaper Enterprise Collaboration Platform 3.0	Flypaper, Inc.
Gaim 0.68	(open source software)
GeekLog 1.3.8-1	(open source software)
GoToMyPC Corporate	ExpertCity, Inc.
iChat AV 1.0	Apple
InfoWorkSpace (IWS) 2.5	Ezenia! Inc.
Jabber WebClient	Jabber, Inc.
Live Communications Server 2003	Microsoft Corporation
Livelink 9.2	Open Text Corporation
Lotus Workplace 1.1	IBM Corporation
Meetrix	Meetrix Inc.
NetMeeting 3	Microsoft Corporation
Oracle Collaboration Suite Release 2	Oracle Corporation
pcAnywhere 11.0	Symantec Corporation
Perspective 3.0	Plethora Technology Inc
PlaceWare Conference Center	Microsoft Corporation
Plumtree Collaboration Server 2.0	Flypaper Inc.
Remote Administrator (Radmin)	Famatech LLC
Session 2.0	Wave Three Software
SharePoint Portal Server 2001	Microsoft Corporation
SharePoint Team Services	Microsoft Corporation
Sightspeed Video Messenger 2003	Sightspeed Inc.
SourceCast 2.0	CollabNet, Inc.

Tool Name & Version	Vendor Name
SourceForge Enterprise Edition 3.3	VA Software Corporation
StarTeam 5.4	Borland Software Corporation
SunForum 3D and 3.2	Sun Microsystems, Inc.
TeamPage	Traction Software, Inc.
TeamSpace 2.0	Flypaper Inc.
Timbuktu Pro Enterprise 2.1.2	Netopia, Inc.
ViaVideo	Polycom, Inc
VIDITalk 1.0	VIDISolutions, Inc
WebEx Meeting Center	WebEx Communications, Inc.
Windows Messenger 5.0	Microsoft Corporation
Blogger Pro	Pyra Labs, Inc.
Jabber Extensible IM (XIM) (server)	Jabber, Inc.
Jabber Messenger (JM) 1.7	Jabber, Inc.
Kubi Client 1.1	Kubi Software
Microsoft Project Central	Microsoft Corporation
Moveable Type	Six Apart Ltd.
Radio Userland	UserLand Software, Inc.
SameTime 3	IBM Corporation
Windchill	PTC
Asynchrony Collaboration Environment	Asynchrony Solutions
eMatrix Global Collaboration Platform	MatrixOne, Inc.
Enterprise Management Server	Groove Networks, Inc
Enterprise Peer Network	NetSilica Inc.
Enterprise Relay Server	Groove Networks, Inc
Flash Communication Server MX 1.5	Macromedia, Inc.
GlowPoint	Wire One Technologies, Inc.
IM Manager 5.0	IMLogic, Inc.
Netilla Service Platform	Netilla Networks, Inc.
OfficePilot	ExecutiveWorks Worldwide, Ltd.
Project Server 2002	Microsoft Corporation
Project.Net 7.4	Project.net, Inc.
SiteScape Enterprise Forum 7.0	SiteScape, Inc.
Visual SourceSafe	Microsoft Corporation
Zaplet Appmail System	Zaplet, Inc.
TeraMedia*Replaced by Session	Wave Three Software
Punch WebDrive Sync Engine	Punch Networks Corporation

Communities of Practice

Communities of Practice are social networks of people within a specific domain, area of expertise, or shared interests who meet regularly for collaboration about their field of interest. These groups are self-governed and operate with the purpose of:

- Developing and spreading new knowledge and capabilities
- Fostering innovation
- Building and testing trust in working relationships

Communities of practice represent a marriage of knowledge management and distributed collaboration. Because regular attendance by all members of the community is virtually impossible, the use of web-based collaboration tools such as wikis or blogs (an online journal that is usually used share information about nearly any topic imaginable) allows members to participate either synchronously or asynchronously based upon their schedules and capabilities at that time.

A wiki is a collaborative method that can be created for specific projects with a set of authorized users. Wikis are designed to create a knowledge repository that can grow and expand by linking to each other or to other resources on the net. Wikis are ideal for communities of practice because they promote applied collective learning, and are developed under the assumption that knowledge and expertise of a particular subject will develop over time and these developments will be found, posted and discussed online. (Schroeder, 2003)

For more information see:

Smith, M., (2003). Communities of Practice. The Encyclopedia of Informal Education. www.infed.org/biblio/communities_of_practice.htm . Last updated 30 January 2005.

Schroeder, R. (2003) Blogging to Disseminate Best Online Learning Practices and Technology News. Presented at the 19th Annual Conference on Distance Teaching and E-Learning.

Computer Vision

One aspect of Human Factors Engineering as identified by NUREG-0711, is Human Performance Monitoring. Technological advancements have introduced image processing methods that can be used to provide specific information about a human's environment and performance within that environment.

Computer Vision is a highly complex method of image processing that is used in artificial intelligence and robotics industries. It can also be used for image recognition which can, in turn, enhance the traditional video surveillance methods. Video surveillance has long been used to track and monitor behaviors and actions. There are drawbacks to video surveillance because single cameras cannot capture all movement and actions, and this is compounded when more than one person is being monitored. Multiple cameras can alleviate this, but unless the monitoring staff is equal to the number of cameras, it is still difficult to process all of the images. In addition, storing video and querying historical video is cumbersome.

Computer Vision offers a method of image recognition that is useful because it provides a simple approach to human identification, recognizing human features, and then storing those features for future tracking. One solution is tracking systems that utilize digital video and computer vision pairs it with peer to peer networking in order to overcome the challenges posed by traditional video surveillance. The use of digital video increases the storage capacity and eases querying. Computer Vision provides a "fingerprint" of sorts, for human recognition. Each person moving through designated points is given a unique "fingerprint" that is stored for easy tracking. As the person moves from one camera to another, that fingerprint is passed along the peer to peer network, increasing storage capabilities, and allowing for the sharing of resources.

For more information see:

Bitsakos K., Tsoumakos D., Roussopoulos N., Aloimonos, Y. (2005). A Framework for Distributed Human Tracking. In Proceedings of the 2005 International Conference on Parallel and Distributed Processing Techniques and Applications (PDPTA'05), June 27-30, 2005 Las Vegas, NV, USA. http://www.cs.umd.edu/~dtsouma/objects/trackP2P.pdf .

CORE

Vitech Corporation has developed a requirements management tool called CORE which allows the user to build behavioral models through a discrete event simulator called COREsim. The CORE product suite uses an object oriented environment to allow users to perform both static requirements analysis(static requirements and attributes of the system) and dynamic requirements analysis (intended behaviors of the system). CORE analyzes and decomposes requirements using graphics and text, and provides traceability that enables instant impact analysis by highlighting affected segments of design.

Information about CORE retrieved December 31, 2007, from:

Vitech Corporation, http://www.vtcorp.com
Volere (2005). Requirements Tools. http://www.volere.co.uk/tools.htm

CREATE (Control Room Engineering Advanced Toolkit Environment)

CREATE was developed by the Halden Virtual Reality Centre and Electricite de France. It is a VR tool that allows users to build virtual models of control rooms (i.e., control suites) and perform a guideline-based verification of ergonomic issues (distances, line of sight, view cones, viewing angles, text size/distance ratios, and reach).

CREATE allows the user to select the guidelines used for the verification including NUREG-0700, ISO standards, and CRIOP (a control room verification / validation tool used by the Norwegian Oil industry).

CREATE is a suite of tools intended for use by managers, designers, reviewers, and other parties involved in a human-centered design process in which the layout and ergonomics of a work environment are in focus. CREATE is particularly suitable to iterative design processes with end-user participation and strict formal review requirements. While it has many potential application areas, it was originally designed specifically to support the design of complex control centers, such as those in the energy and process industry. CREATE combines advanced

interactive 3D technology with web-based file management and version control, providing an integrated package that supports and traces the various stages of the design process.

CREATE has been designed to support an interactive design methodology, where a room or environment layout is refined and tested many times before a final design is reached. This contrasts with traditional design methods where the number of possible design iterations is limited by the cost of constructing adequate physical mock-ups. When CREATE is used, it is not necessary to build an inflexible physical mock-up, so greater emphasis can be placed on finding an optimal design or planning solution. Layouts are created using a drag-and-drop user interface. The user drags objects directly into a 3D model of a room. The software automatically maintains associations between objects, such as which desk a telephone has been placed on so that groups of objects can be intuitively moved around. Formal design testing against guideline such as NUREG 0700 and CRIOP can be performed with the assistance of the system's review data management facilities, and a selection of powerful 3D measurement tools and manikins. The same 3D tools are available to the designer for informal testing as the layout is constructed.

Figure A1 CREATE Screen Designs

Information about CREATE retrieved December 31, 2007, from:

http://www2.hrp.no/vr/products/create/download/pdf/hvrc-create-brochure.pdf

CSDT (Crew Station Design Tool)

The Crew Station Design Tool (CSDT) allows designers to visualize and optimize their choices of controls and displays, and the position of those elements in a workstation. It automatically determines the optimum arrangement of controls and displays based upon sound human engineering and ergonomics principles. In order to accomplish this, the CSDT communicates with three different software tools: 1) the Improved Performance Research Integration Tool (IMPRINT) - a task network modeling tool, 2) Open Inventor - a three-dimensional graphics environment, and 3) Jack - a human figure (anthropometric) modeling tool.

Figure A2 Sample Jack Screen

Using the results of a task analysis as its foundation, the CSDT helps designers select the most appropriate control for a task and build an IMPRINT (task network) model of the activities performed in their desired workstation. Once executed, the IMPRINT model identifies operator-task conflicts and provides frequency-of-use data for each control and display. The CSDT uses this data to place the selected controls and displays in Open Inventor's three-dimensional environment. Finally, the suggested arrangement and the data acquired from the IMPRINT model are used to generate and execute a three-dimensional human figure model in Jack. Jack simulates the physical behavior of humans interacting in the workstation and allows designers to visualize the feasibility of certain tasks (i.e., can a human see and actuate a control within the specified environment). When the designer has finished viewing the Jack model, he or she can return to any part of the CSDT to make adjustments in their design.

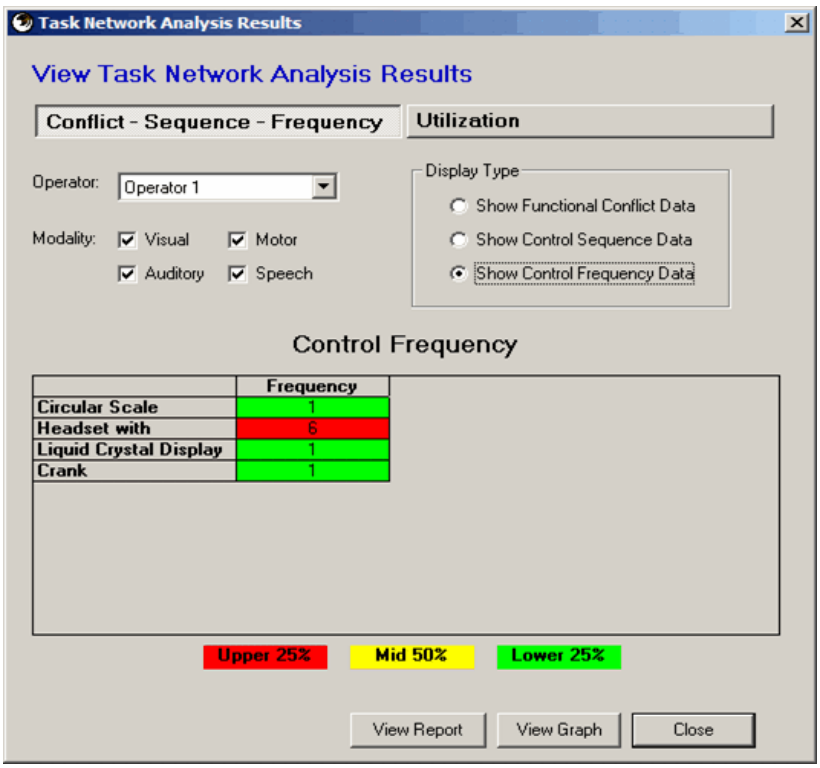

Figure A3 Sample CSDT Screen Display

Some of the key features of the CSDT are:

- A library of controls and displays and a query system that helps designers select the best control or display for a particular task
- A library of North American location conventions (stereotypes) for controls and displays in different types of workstations
- Options for importing data
- Automatic code generation for the task network model
- Automatic data collection and generation of reports, including operator utilization and the suggested coordinates for each control and display in the crew station

Information about Crew Station Design Tool retrieved December 31, 2007, from:

http://www.maad.com/index.pl/crew_station_design_tool

Data Flow Diagrams

Simply put, the Data Flow Diagram (also known as a process model) is a graphical model that shows the inputs, processes, storage and outputs of a system produced in a structured analysis. They are beneficial in that they display all of the system's functional requirements and they are easy to read and follow.

In a DFD, the system can be represented at various levels of abstraction so that higher level processes are decomposed into lower-level processes with more detail. Rounded boxes

represent processes, arrows represent the directional flow of the data, and the open ended rectangles represent data stores. A closed rectangle represents external agents (also known as terminators) which are generally the source or destination of data outside the system.

Systems can often be complex and as such are prone to redundancy and information gaps. To minimize this complexity, DFDs utilize Miller's number, or the rule of 7 ± 2, to determine the number of functions each flow diagram can be broken into. This rule is based upon the principle that a person can only process or remember between 5 and 9 chunks of information before reaching information overload. Ensuring that no single DFD has more than 7 ± 2 processes or data flows ensures that the DFD will be simple enough to understand while complex enough to capture the necessary requirements.

In addition to using Miller's Number, the DFD should demonstrate evidence of balancing to ensure that the data flows consistently. Specifically:

- There should be no differences in data flow content between a process and its decomposition
- Data inflows should have corresponding data outflows
- Data outflows should have corresponding inflows.

For more information see:

Satzinger, J., Jackson, R., & Burd, S., (2004). Systems Analysis and Design in a Changing World. Boston, MA., Thompson Course Technology.

DELMIA Human

Delmia Human is a suite of human simulation and Human Factors (HF) tools specifically geared towards understanding, and optimizing, the relationship between humans and the products they manufacture, install, operate and maintain. It provides modeling technology to create and manipulate advanced, user-defined digital human manikins, referred to as "workers", and simulate task activities. It allows users to create detailed customized manikin's for an intended target audience, specifically analyze how the manikins will interact with objects in the virtual environment, and determine operator comfort and performance in the context of a new design.

Information about DELMIA Human retrieved March 10, 2008, from:

http://www.delmia.com/gallery/pdf/DELMIA_V5Human.pdf

Department of Energy Lessons Learned Program

The Department of Energy (DOE) developed a lessons learned program (Carnes & Breslau, 2002). The purpose of the DOE lessons learned program is to allow senior management to use the work of the past years for performance improvement. The DOE's Lessons Learned program is designed on three key components:

1. A formal community of practice of lessons learned practitioners responsible for coordinating local programs and integrating them with the DOE Lessons Learned program.
2. A technical standard that provides guidance for developing and maintaining lessons learned programs.
3. An electronic system that links the elements of the program with DOE personnel and contractors so that they can be accessed and utilized in a timely manner.

For more information see:

Carnes, W.E., & Breslau, B. (2002). Lessons Learned: Improving Performance Through Organizational Learning. Paper presented at IEEE 7th Human Factors Meeting, Scottsdale, AZ.

DOORS (Dynamic Object Oriented Requirements System)

DOORS is an Information Management and Traceability (IMT) tool. It is used primarily for requirements engineering. Requirements are handled within DOORS as discrete objects. Each requirement is tagged with an attributes which allow the user to select a subset of tasks for specialized tasks. DOORS includes a web-based traceability system that allows users to submit and review proposed requirements changes and change justification. Multi-level traceability is provided through the use of links between all objects. Additionally, DOORS provides reporting utility for impact and traceability analysis, and for identifying missing links across all levels or phases of the project.

Information about DOORS retrieved December 31, 2007, from:

Telelogic AB, http://www.telelogic.com/
Volere (2005). Requirements Tools. http://www.volere.co.uk/tools.htm . Last updated November 2005.

DUTCH (Designing for Users and Tasks from Concepts to Handles)

DUTCH is an emerging integrated design method, rooted in hierarchical task analysis that has been used throughout the development cycle and is supported by CASE tools. It is intended to be used by multidisciplinary teams designing complex, interactive, groupware systems.

DUTCH is a very structured process encompassing task analysis, representation, and tool support. The process consists of:

- Groupware Task Analysis, supported by workflow editors, task trees and template tools such as EUTERPE.
- Detailed design of functionality, dialog, and representation
- Early evaluation using scenarios and use cases, later evaluation using mockups and prototypes

Information about DUTCH retrieved December 31, 2007, from:

http://www.cepis-upgrade.org/issues/2003/1/upgrade-vIV-1-low-res.pdf

See also:

Van der veer, G. & van Welie, M. (2004). DUTCH: Designing for Users and Tasks from Concepts to Handles. In Diaper, D. & Stanton, N. (Eds.) The Handbook of Task Analysis for Human-Computer Interaction. Mahwah, New Jersey: Lawrence Erlbaum Associates.

EasyRM

EasyRM requirement manager is a component-based CASE tool targeting initial stages of project life cycle, when the project framework has been established, project requirements are gathered and synchronized and glossaries of project-specific terms and phrases are compiled. EasyRM provides users with the following facilities:

- Creation, description, modification and progress tracking of project requirements.
- Classification of requirements, including the ability to have several independent classifications of the same requirement set.
- Specification of relationships between requirements, including requirement decompositions, dependencies, correlations, conflicts, etc.
- Maintenance of semantic links from requirements to glossary terms and phrases used in requirement specifications
- Maintenance of traceability links from requirements to information sources where these requirements have originated.

Information about EasyRM retrieved December 31, 2007, from:

Cybernetic Intelligence GmbH, http://www.easy-rm.ch/
Volere (2005). Requirements Tools. http://www.volere.co.uk/tools.htm . Last updated November 2005.

ECAT (Engineering Control Analysis Tool)

The Engineering Control Analysis Tool (ECAT) is currently being developed by Micro Analysis & Design (now Alion Science and Technology) for the Navy. ECAT is based on NUREG/CR-1278 (Handbook of Human Reliability Analysis with Emphasis on Nuclear Power Plant Applications,1983). It allows developers to create scenario events and then explore the failure propagation associated with system failures. After a system failure occurs, ECAT looks at the alerts and human actions, which can lead to a successful recovery of the system, or a system failure. While running the model created by ECAT, the Human Error Potential of the users at different times along the failure propagation stream is calculated. A developer can look at Human Error Potentials for a specific part of the system, such as an auditory alert, or can look at how it changes over time within the context of the scenario. The Human Error Potential not only looks at a user's workload and the system they are interacting with, but also the experience level and stress level of the user. The developer can iteratively test their proposed system by redesigning areas found to produce high High Error Potentials and running the model again. Although ECAT has been developed for naval shipboard engineering operational tasks, it shows potential to be applicable to other diverse complex environments.

For more information, see:

Alion Science and Technology
4949 Pearl E. Circle
Boulder, CO 80302

Ecological Interface Design

Ecological Interface Design (EID) is an approach to the design of complex sociotechnical systems (such as a power plant). The main goal of EID is to provide users within the system with the constraints and complex relationships within the system. This awareness optimizes the decision making process by making the user more aware of the constraints of the environment he is working in.

EID is founded on two main theories - abstraction hierarchy (Rasmussen, 1985) and the skills, rules, knowledge taxonomy (Rasmussen, 1983).

The abstraction hierarchy is a framework for modeling a system, or work domain. Vicente (2002) defines it as "a stratified hierarchy characterized by a structural means-end relation between adjacent levels". Higher levels of the hierarchy contain functional information about the state of the functions or purposes the system is intended to meet. Lower levels contain more detailed information about the objects within the system.

The skills, rules, knowledge taxonomy describes three different methods in which people interact with their environment.

- Skills based behavior - direct manipulation or interaction with the environment
- Rule-based behavior - association of a perceptual cue in the environment with an action
- Knowledge based behavior - analytical problem solving

Utilizing these two theories, EID establishes a framework for design that seeks to reduce the amount of cognitive interaction the human has with the work environment so that he is better equipped to cope with unanticipated activity within the environment. (Vicente)

For more information see:

Vicente, K., (2002), Ecological Interface Design: Progress and Challenges. Human Factors, Vol. 44, No. 1, Spring 2002 pp. 62-78.

Rasmussen, J. (1985), The role of hierarchical knowledge representation in decisionmaking and system management, IEEE Transactions on Systems, Man and Cybernetics, SMC-15, 234-243.

Rasmussen, J. (1983). Skills, rules, and knowledge: signals, signs and symbols, and other distinctions in human performance models, IEEE Transactions on Systems, Man, and Cybernetics, SMC-13, 257-266.

ELETRONUCLEAR

ELETRONUCLEAR, the owner and operator of nuclear power plants in Brazil demonstrated the value of Knowledge Management in 2001. ELETRONUCLEAR was faced with the realization that the bulk of its technical personnel would be retiring within 5-10 years. As a result, gaps in technical know-how and experience could leave them with an inexperienced workforce which could in turn leave them open to higher frequencies of human error and safety breaches. Over the course of a year, ELETRONUCLEAR developed an electronic tool that required self-evaluation by members of management to compile an electronic data bank. This data bank was then used to produce analytical reports which allowed management to identify potential knowledge bottlenecks, and develop a process for addressing those bottlenecks.

For more information see:

Lipecki, W. (2002). Determination of Technological Know-How of ELETRONUCLEAR. Paper presented at IEEE 7th Human Factors Meeting, Scottsdale, AZ.

Embedded Training

Embedded training systems can offer on-line access to training course materials. Scenario planning and execution capabilities may be added to the on-line training as part of scenario training as well. Other forms of embedded training include inter-operation with training simulators which provide simulation and training functionality to the user to either re-enforce newly trained concepts or increase retention of previously acquired skills. Some simulators utilize training courseware and hypermedia to provide hands-on, performance-based instruction, thereby reinforcing training.

Information about embedded training retrieved December 31, 2007, from:

https://www.spider.hpc.navy.mil/index.cfm?RID=TTE_OT_1000005

Envision/Ergo

Envision/Ergo is a human motion and task analysis tool to rapidly evaluate multiple scenarios. In Envision/Ergo, human motion is rapidly prototyped or "captured" into the virtual environment, enabling quick and precise analysis of reach, lift, posture, cycle time, visibility and motion. Analysis capabilities include range of motion, National Institute for Occupational Safety and Health (NIOSH) lifting guidelines, GARG Energy Expenditure Analysis, upper limb repetitive motion assessment, and Methods Time Measurement (MTM-UAS).

Information about Envision/Ergo retrieved December 31, 2007, from:

http://www.delmia.com/ENVISION/ERGO

Entity Relationship Diagram

The Entity Relationship Diagram is similar to the Data Flow Diagram in that it is data centered. However, in the ERD, the focus is placed not on the data flow, but on the concept of data as entities with descriptive attributes and the relationships with other entities within the system. The

ERD is a graphical model of the data needed by a system, including which information is stored, and the relationship among them.

Relationships between data can be one to one (as in a social security number to a person…the person can only have one social security number that is exclusive to him); one to many (as in the case of a mother to a child…a mother can have many children, but each child only has one biological mother); many to many (as in the case of a teacher/student relationship…students may have many teachers and teachers have many students).

ERD notation is relatively simple to understand. The boxes represent the data entities and their attributes. The diamonds represent the actions taken by the entities, and the lines represent the flow of data and the relationship between the entities. Lines with the crow's feet indicate a one-to-many relationship.

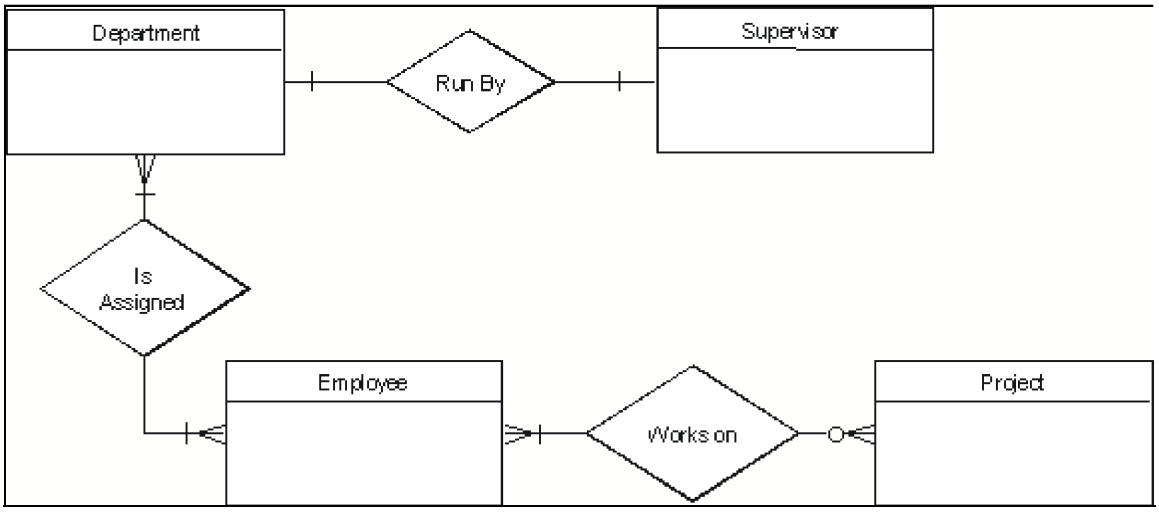

Figure A4 Entity Relationship Diagram

In the figure above, an employee may work on many projects, and projects may have many employees assigned to it. However, Departments only have one supervisor, and supervisors only run one department.

As with the DFDs, it is important that ERDs maintain a level of quality so as to maximize the effectiveness of its use as a requirements analysis tool. To ensure this level of quality, relationships need to be closely evaluated so that one-to-one relationships are truly one-to-one, if needed. In addition, all relationships need to be traceable to avoid redundancies or gaps.

For more information see:

Satzinger, J., Jackson, R., & Burd, S., (2004). Systems Analysis and Design in a Changing World. Boston, MA., Thompson Course Technology.

EPIC (Executive Process-Interactive Control)

EPIC provides a framework for constructing models of human-system interaction that are accurate and detailed enough to be useful for practical design purposes. EPIC represents a synthesis of data on human perceptual/motor performance, cognitive modeling techniques and task analysis methodology implemented in the form of computer simulation software. Visual, auditory and tactile perceptual processors receive inputs from simulated physical sensors. The output of these processors is sent to the working memory of the cognitive processor. The cognitive processor consists of working memory, long-term memory, production memory and a multi-match, multi-fire production rule interpreter (or production system) called PPS. The cognitive processor, on receiving input from the perceptual processors, performs the cognition necessary for the task being modeled. It then sends output commands to the ocular, vocal and manual motor processors.

The goal of EPIC is to develop a predictive theory of human performance and cognition that is accurate and practical enough to simulate the human-machine system in system design methodology.

Information about EPIC retrieved December 31, 2007, from:

http://www.eecs.umich.edu/~kieras/epic.html

EPRI Strategic Human Performance Program

The EPRI Strategic Human Performance Program acknowledged the potential loss of intellectual assets within the power industry, and was developed to support research into solutions for capturing undocumented worker-job knowledge in electric utilities. Researchers for this study interviewed several candidates to determine what methods were currently in use for capturing undocumented knowledge. The methods identified were:

- Applied cognitive task analysis - Three interviewing methods which help analysts to extract information about the cognitive demands and skills required for a task:
- Task Diagrams
- Knowledge Audits
- Simulation Interviews
- Critical Incident and Critical Decision methods - Methods which document past critical incidents or decisions.
- Lessons Learned documentation
- The use of think-aloud protocols during work, simulation, or reconstructed scenarios such as digital video recording.

This study also emphasized the need to store and provide access to this tacit knowledge, noting that identifying the knowledge gaps and capturing knowledge is not enough. In order for this knowledge to be effective for design plans for modernization or construction, it needs to be readily available. The following methods were identified by participating candidates as approaches to knowledge storage, retrieval, and presentation:

- Concept Maps - Graphical brainstorming
- Knowledge repositories - A computer system or database that captures and analyzes knowledge assets and allows users to filter and query based upon certain criteria.
- Communities of Practice - Collaborative forums or working groups consisting of industry experts.

After analyzing the various methods in use by the study participants, EPRI developed a four step prototyping process intended to provide guidelines for the identification, elicitation, storage, retrieval, and presentation of knowledge to be captured.

For more information see:

Gross, M., Hanes, L., and Ayres, T. (2002) Capturing Undocumented Worker-Job-Knowledge at Electric Utilities: The EPRI Strategic Project. Paper presented at IEEE 7th Human Factors Meeting, Scottsdale, AZ.

ErgoMaster

ErgoMaster is a suite of ergonomic analysis software modules. The system's applications include ergonomic analysis, risk factor identification, training, as well as job and workstation redesign. Its suite of modules and tools assists in the analysis of lifting tasks, repetitive tasks, awkward postures, office ergonomics and many other areas.

The ErgoMaster is comprised of several different analysis modules. These modules are designed to satisfy the evaluation needs of a specific area of interest and are categorized as follows:

- Lift Analyst- provides tools to evaluate and document materials handling activities and perform biomechanical predictions for the lower back. These tools include Materials Handling Assessment, 2-D Biomechanical Prediction, Revised National Institute for Occupational Safety and Health (NIOSH) Lifting Equation, and Discomfort Survey.
- Task Analyst- includes various tools to evaluate task design and perform job analysis. These tools include Task Assessment, Tool Assessment, Rapid Upper Limb Assessment (RULA), Work/Rest Cycles, and Discomfort Survey.
- Biomechanics Analyst- enables users to easily interface with the University of Michigan's 3D Static Strength Prediction Program (SSPP) in 2D mode (which is purchased directly from the University of Michigan Software) by simply clicking on the joint positions in the digital image.
- Posture Analyst- provides tools to evaluate an individual's posture as it pertains to range-of-motion, biomechanics and anthropometrics. These tools include Posture Assessment, RULA, Anthropometric Survey, Dimensional Analysis, and Discomfort Survey.
- Workstation Analyst- provides tools for the evaluation of industrial and/or office environments for ergonomic risk factors. This includes the assessment of furniture and equipment. These tools include Workstation Assessment, Video Display Assessment, Anthropometric Survey, Tool/Product Assessment, and Discomfort Survey.

- Ergo Product Database- is a resource of ergonomic related products that may be used as recommendations to environmental layout or tool/equipment selection. This database does contain sample products but is encouraged to be user defined.
- Getting Started- contains general tools to begin an ergonomic evaluation. General Information, Discomfort Survey.

Information about ErgoMaster retrieved December 31, 2007, from:

http://www.nexgenergo.com/ergonomics/ergomast.html

FAST (Fatigue Avoidance Scheduling Tool)

FAST is a fatigue forecasting system that produces fatigue predictions based on the Sleep, Activity, Fatigue, and Task Effectiveness (SAFTE™) model invented by Dr. Steven Hursh of Science Applications International Corporation (SAIC). The SAFTE™ model has received a broad scientific review and the Department of Defense (DoD) considers it the most complete, accurate, and operationally practical model currently available to aid operator scheduling (Hursh, etal., 2004). The FAST scheduling tool uses the model to compare schedules in terms of predicted performance effectiveness. FAST allows easy entry of proposed schedules and generates graphical predictions of performance along with tables of estimated effectiveness scores for objective comparison. Optimal schedules may be selected based on average effectiveness for proposed work periods or mission critical events.

Information about FAST retrieved December 31, 2007, from:

http://www.dtic.mil/matris/ddsm/srch/ddsm0219.html

See also:

Hursh S.R.; Redmond D.P.; Johnson M.L.; Thorne D.R.; Belenky G.; Balkin T.J.; Storm W.F.; Miller J.C.; Eddy D.R.Fatigue Models For Applied Research in Warfighting. Aviation, Space, and Environmental Medicine, Volume 75, Supplement 1, March 2004, pp. A44-A53(1) Aerospace Medical Association. Retrieved from http://www.ingentaconnect.com/content/asthma/asem/2004/00000075/A00103s1/art00005

Foresight

Foresight is an integrated modeling and simulation tool suite that provides a complete environment for system design space exploration. The Foresight tool suite includes the following capabilities:

- FS/Model - model editors that allow users to create flow diagrams, and executable system models.
- FS/Sim - A Discrete event simulation tool
- FS/Vis - A Data visualizer used to display simulation results
- FS/AltiaLite - A Human interface prototyper
- FS/Doc - Provides automatic generation of documents from the system model

- FS/RQIF - Links requirements management tools with system model/design, providing traceability.

Information about Foresight retrieved December 31, 2007, from:

Foresight Systems, Inc., http://www.foresightsystems-mands.com/
Volere (2005). Requirements Tools. http://www.volere.co.uk/tools.htm . Last updated November 2005.

HCDA (Human Centered Design Advisor)

The HCDA, developed by McDonald Research Associates in conjunction with the Naval Air Warfare Center, provides guidance on implementing and executing the human systems engineering process. It references human factors issues contained in IEEE 1220-1998 (IEEE Standard for Application and Management of the Systems Engineering Process). When systems engineers are developing specific requirements, the HCDA recommends human factors oriented requirements from the systems engineering community as opposed to coming from the human factors community. As the design progresses, the HCDA gains sufficient knowledge of the design task at hand to provide context-specific advice from the human factors community on how to fulfill the human factors requirements.

For more information see:

McDonald, B. and Campbell, G., Integrating Human Engineering Requirements into the Early Systems Engineering Process., Presented at the Interservice/Industry Training Simulation and Education Conference (I/ITSEC) 1999. Retrieved December 31, 2007, from http://www.manningaffordability.com/s&tweb/PUBS/HF013/HF013.htm

HFE-AT (Human Factors Engineering Analysis Tool)

The Human Factors Engineering Analysis Tool (HFE-AT) is a software program that allows the quick and easy selection of applicable regulatory guidelines for a given situation. The HFE-AT was developed by Westinghouse Savannah River to help people more readily access and use the guidelines found in NUREG 0700. A team of Human Factors Experts categorized all of the guidelines found in NUREG 0700 into the following two categories:

- System technical applicability (computer based or non-computer based)
- System functional applicability (safety based or non-safety based)

The guidelines were further classified into the following three types:

- General concept: Highest level or most general description of a topic that is common to two or more guidelines.
- Supporting detail: Guidelines that address specific details, associated with general concepts.
- Stand-alones: Any other guideline that is sufficiently important to be considered individually.

The HFE-AT also aids designers in their evaluation by tracking the status of the analysis as it is performed.

HFE-AT consists of a Microsoft Access database containing guidelines from NUREG-0700 and a graphical user interface. 1500 guidelines from NUREG-0700 were screened according to safety and computer-relevance. To perform a review, the reviewer specifies that the review is safety or non-safety and computer or non-computer related, and the system will automatically select a subset of guidelines. The reviewer can also manually select guidelines or groups of guidelines that apply to the review. The reviewer then steps through the list of guidelines, commenting on how the current design (as he understands it) fulfills the guidelines. In February 2005, Westinghouse updated the tool to reflect NUREG-0700 Revision 2. Six hundred new guidelines were added, mainly in the areas of information display, the user-system interface, and automation.

Information about HFE-AT retrieved December 31, 2007, from:

http://www.srs.gov/general/busiops/tech-transfer/human.htm
http://www.srs.gov/general/busiops/tech-transfer/techbrif/TB0014%20human%20factors.pdf

IBM Rational ClearCase and ClearQuest

IBM Rational ClearCase provides life cycle management and control of software development assets. With integrated version control, automated workspace management, parallel development support, configuration management, and build and release management, Rational ClearCase provides the capabilities needed to create, update, build, deliver, reuse and maintain business-critical assets.

IBM Rational ClearQuest enables better insight, predictability and control of the software development process. Through flexible workflow management and defect and change tracking across the application life cycle, Rational ClearQuest helps to automate and enforce development processes, manage issues throughout the project life cycle, and facilitate communication between all stakeholders across the enterprise.

Information about IBM Clear Case and ClearQuest retrieved December 31, 2007, from:

IBM Rational Software, http://www-306.ibm.com/software/rational/
Volere (2005). Requirements Tools. http://www.volere.co.uk/tools.htm . Last updated November 2005.

iBracelet

iBracelet is a Human Activity Recognition tool developed at Intel's Seattle Lab. It is a glove mounted RFID reader that tracks hand movements. RFID tags are placed on objects that the user comes in contact with, and the RFID reader on the Bracelet tracks the user's interaction with those objects. Intel is currently using iBracelet in onr of their fabrication facilities to assist technicians with preventive maintenance. The objective is to track the technicians as they perform their checklist of activities in an effort to identify better methods of performing preventive maintenance.

Information about iBracelet retrieved December 31, 2007, from:

http://www.intel-research.net/seattle/about2.asp

See also:

Smith, J., Fishkin, K., Jiang, B., Mamishev, A., Philipose, M., Rea, A., Roy, S., and Sundara-Rajan, K. (2005). RFID-Based Techniques for Human-Activity Detection Communications of the ACM, September 2005, Vol. 48, No., 9.

ICS-CTA (Interactive Cognitive Subsystems to Cognitive Task Analysis (CTA))

Interactive Cognitive Subsystems to CTA (ICS-CTA) is a cognitive architecture designed to be applied to an existing task analysis. According to May (2004), "a CTA in ICS attempts to identify the cognitive resources than an individual operator would need to employ in performing a task." It is used to point out moments of cognitive overload during task execution. ICS-CTA is likely to be used to analyze individual operators, and the output is more qualitative than say that from a Goals, Operators, Methods, and Selection Rules (GOMS) analysis.

For more information, see:

John May, University of Sheffield, http://www.shef.ac.uk/jonmay/publist99.htm

IETM (Integrated Electronic Technical Manuals)

With the Interactive Electronic Technical Manual, or IETM, maintenance and troubleshooting procedures, parts information, theory of operation and illustrated graphics can be loaded on a lightweight portable computer to go where the technician goes. IETM contains all information required by technicians to perform system maintenance. (Taken directly from http://www.boeing.com/defense-space/lss/techdata/ietm.htm)

Information about IETM retrieved December 31, 2007, from:

MIL-STD-3001, http://edm.monmouth.army.mil/pubs/ietm.html
http://www.boeing.com/defense-space/lss/techdata/ietm.htm

iGlove

iGlove is an earlier prototype of the previously mentioned iBracelet. Also developed in Intel's Seattle Lab, it is a glove mounted RFID reader to track hand movements. While more cumbersome than the iBracelet, it acts in the same manner. RFID tags are placed on objects within the user's environment, and as the user interacts with those objects, information about that interaction is sent to a central repository that logs the user's activities. It has been envisioned as a valuable tool for tracking the activities of elderly who, though not totally dependent on assistance, still require monitoring. This application could easily be extended to more complex socio-technical environments where monitoring human performance in real time is crucial.

Information about iGlove retrieved December 31, 2007, from:

http://www.intel.com/research/network/seattle_human_activity_recognition.htm

See also:

Smith, J., Fishkin, K., Jiang, B., Mamishev, A., Philipose, M., Rea, A., Roy, S., and Sundara-Rajan, K. (2005). RFID-Based Techniques for Human-Activity Detection Communications of the ACM, September 2005, Vol. 48, No., 9.

IMPRINT (Improved Performance Research Integration Tool)

IMPRINT, developed by the Human Research & Engineering Directorate of the U.S. Army Research Laboratory, is a stochastic network modeling tool designed to help assess the interaction of soldier and system performance throughout the system lifecycle--from concept and design through field testing and system upgrades. IMPRINT addresses the following issues during Army systems acquisition:

- System Performance and Random Access Memory (RAM) Criterion Development Aid - Imprint supports the analyst in developing clear system performance requirements and conditions so that hardware/software designers will know what the system will have to do to achieve mission success. This is accomplished by using a discrete event simulation tool as the engine to perform task analysis, and subsequent soldier-system task allocation.
- Manpower Constraints Estimation Aid - Imprint provides the ability to import Logistics Support Analysis Reports (LSAR) that can provides crew size limits to hardware/software designers so that they do not design for unavailable numbers of operators and maintainers.
- Personnel Constraints Estimation Aid - The purpose of this product is to provide designers with a description of the significant soldier characteristics that explain and limit the probable operator and maintainer populations.
- Manpower and Personnel Based System Evaluation Aid - The purpose of this product is to determine the number of soldiers per job required to operate and maintain system hardware. This product predicts the operations and maintenance jobs required and the number of operations and maintenance personnel per job per system.

In addition to a heavy simulation component, these tools include a variety of mathematical programming and optimization methods. This work, started in the mid-1980s, represents an early attempt at developing tools to support what is now being widely referred to as simulation-based acquisition.

Information about IMPRINT retrieved December 31, 2007, from:

http://www.arl.army.mil/ARL-Directorates/HRED/imb/imprint/Imprint7.htm

Information Engineering

Information Engineering (IE) is another method that follows the traditional requirements analysis approach. This method refines the structured approach by centering around a strategic plan to define all of the information systems that the organization needs to achieve the organizational mission. This method is a more holistic approach in that it includes definitions of the business functions and activities that the system needs to support. Rather than focusing on data flows, or data relationships, IE focuses on strategic planning with the use of data modeling and automated tools.

IE is a rigid, goal oriented method of development and analysis that is designed to address enterprise wide information processing requirements. In this method, the output of each phase specifies the inputs for the next phase. IE process models display the following types of information:

- Decomposition of processes into other processes
- Dependency relationships among processes
- Internal processing logic

IE relies on the Process Decomposition Diagram. The Process Decomposition Diagram uses the same notation as the structured Data Flow Diagram. The process diagram also supports hierarchical relationships among processes at different levels, and these processes are decomposed on separate pages that describe the order of processes and their interaction with data stores called process dependency diagrams. The difference, however, is that the IE approach is looking at the overall system picture and making assumptions about the flow of the data…namely that processes read and write data to and from the database. For this reason, the process dependency diagram does not include data flows among data and processes because doing so might introduce unnecessary physical assumptions about implementation.

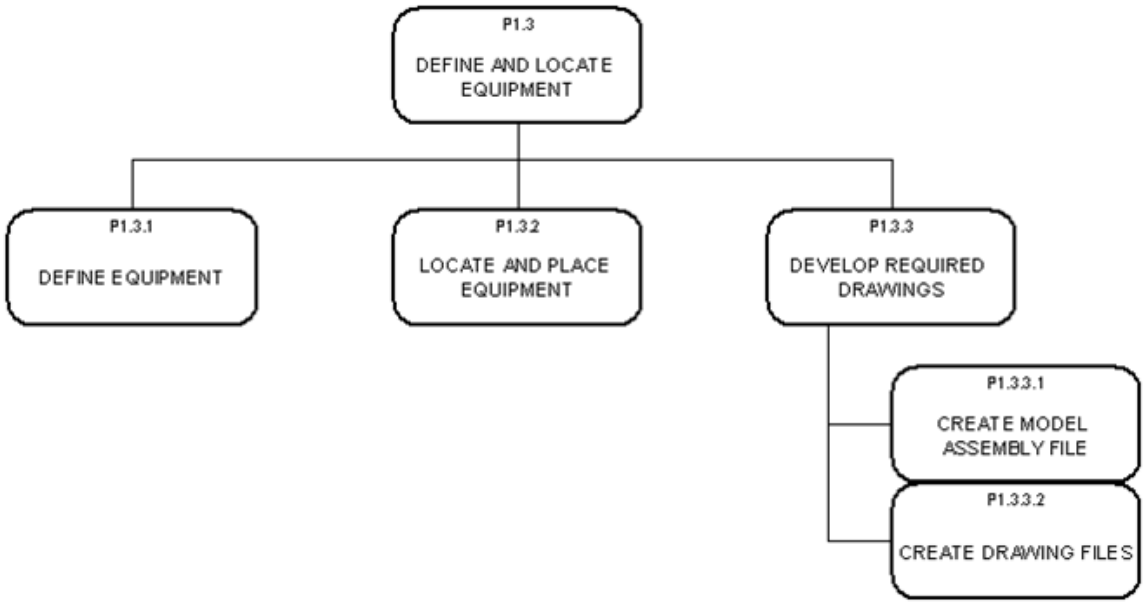

Figure A5 Process Decomposition Diagram

IE operates on the principle that the question of "When" and "Where" with regard to data flows are design questions, and are therefore not addressed until the systems design phase.

For more information see:

Satzinger, J., Jackson, R., & Burd, S., (2004). Systems Analysis and Design in a Changing World. Boston, MA., Thompson Course Technology.

Information Link Analysis

Link analysis has historically been used within human factors to look at the relationships be between people, the things they work with, and the space available to place both. In the world of the internet, link analysis is now used to find related information on the web. As more content migrates to the web or networked data stores, link analysis will continue to grow as a valuable tool for getting to useful information quickly.

Information about Link Analysis retrieved December 31, 2007, from:

http://linkanalysis.wlv.ac.uk/
http://www.kdnuggets.com/software/link-analysis.html

IPME (Integrated Performance Modeling Environment)

The Integrated Performance Modeling Environment (IPME) is a Unix-based integrated environment of simulation and modeling tools for answering questions about human-machine systems that rely on human performance to succeed. IPME provides:

- A realistic representation of humans in complex environments
- Interoperability with other models and external simulations
- Enhanced usability through a user friendly graphical user interface

IPME provides a full-featured discrete event simulation environment built on the Micro Saint modeling software. Additionally, it provides added functionality to enhance the modeling of the human component of the system. Finally, it has a number of features that make it easier to integrate IPME models with other simulations on a real-time basis including TCP/IP sockets and tools for developing simulations that adhere to the Higher Level Architecture (HLA) simulation protocols that are becoming standard throughout the world.

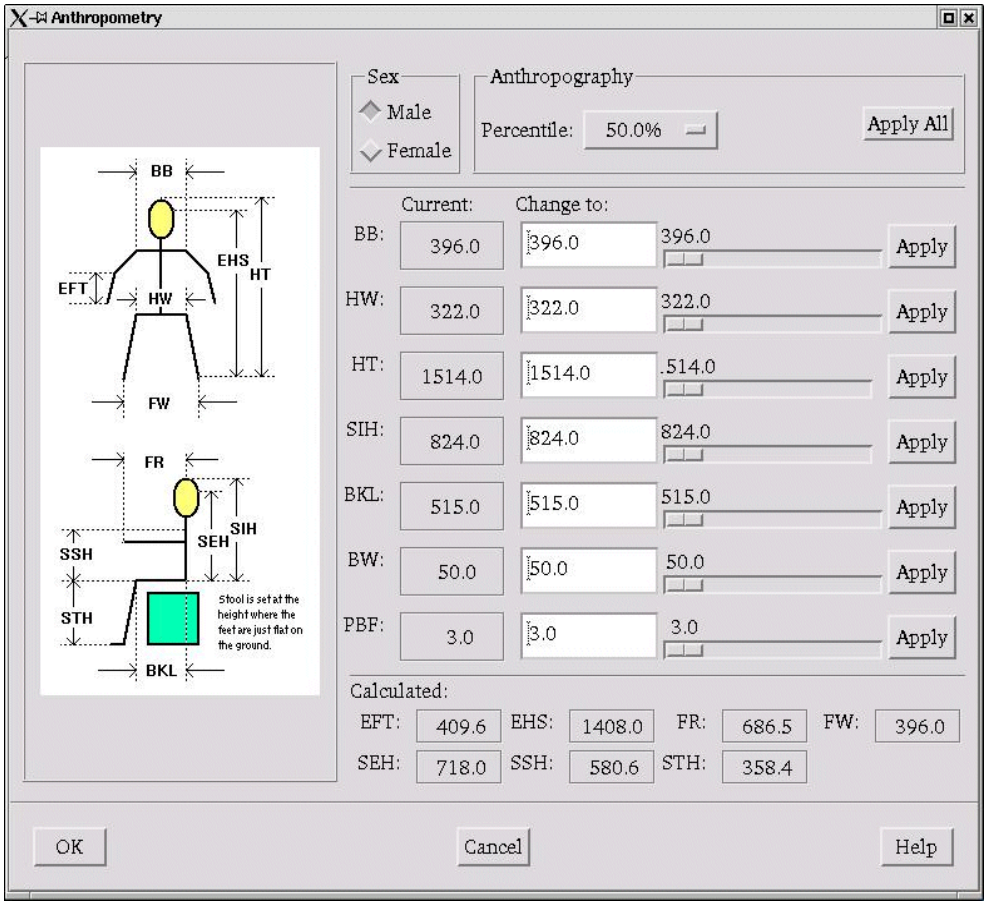

Figure A6 Sample IPME Screen Design

Key Features of IPME:

- Environment Model
- Operator Characteristics
- Performance Shaping Functions
- Information Processing / Perceptual Control Theory Dynamic Scheduler (IP/PCT)
- Prediction of Operator Performance (POP) Workload Measurement
- Measurement Suite
- Micro Saint Human Operator Simulator (MS HOS) Engine

Information about IPME retrieved December 31, 2007, from:

http://www.maad.com/index.pl/ipme

IRqAR (Integral Requisite Analyzer)

IRqAR adopts a holistic Requirements Engineering approach to specification development and management by providing a complete suite of tools in one application. This approach incorporates the following standard Requirements models:

- Requirements Capture
- Requirements Management
- Requirements Analysis
- System Specification building
- Specification validation (specification vs. requirements)
- Acceptance Tests management
- Requirements Organization & Classification

Information about IRqAR retrieved December 31, 2007, from:

TCP Sistemas e Ingenieria, http://www.irqaonline.com/
Volere (2005). Requirements Tools. http://www.volere.co.uk/tools.htm . Last updated November 2005.

ISMAT (Integrated Simulation Manpower Analysis Tool)

ISMAT is a discrete-event simulation tool for evaluation of system manning concepts early in development. ISMAT is currently a Phase II Naval Small Business Research Initiative (SBIR) being used to evaluate both new classes of US Navy ships and to modernize older ships, which is a challenge akin to the Generation II hybrid NPPs and the Generation III and III+ NPPs. The purpose of ISMAT is the following:

- Address the allocation of functions and tasks to humans and to advanced technologies
- Identify additional training requirements resulting from the introduction of new technologies
- Predict relative costs

ISMAT incorporates task characteristics, task timelines, situational awareness, as well as operator Knowledge, Skills and Abilities (KSA's) into a dynamic human performance simulation framework. ISMAT also assists designers in assessing the impact of reduced manning levels on performance in various dimensions of the system. These include the levels of automation required, and the allocation of tasks to human operators of the system. Through iterative use, ISMAT can help analysts determine the best allocation of tasks to personnel and the level of automation necessary to handle crew overload situations. By performing this analysis before the prototype stage and by varying assumed level of automation, task allocations, crew characteristics, mission scenarios, and execution goals, considerable time and expense can be saved by eliminating faulty design options.

Information about ISMAT retrieved December 31, 2007, from:

http://www.dawnbreaker.com/forums/navy05/presentations.php

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Isolde:U2T (Integrated Software and Online Documentation Environment: Unified Modeling Language to Task Extraction Tool)

The closest thing to a "task analysis translator" is Isolde's UML to Task Extraction Tool (U2T). This tool extracts task model knowledge from design models created by system engineering groups in the Unified Modeling Language (UML) for use in performing task analysis. The Integrated Software and Online Documentation Environment is a tool developed by the Information at Australia's CSRIO, headed by Cecile Paris.

Information about Isolde:U2T retrieved December 31, 2007, from:

Cecile Paris, CSIRO, Australia, http://www.ict.csiro.au/staff/Cecile.Paris/From-CMIS/Projects/Isolde/index.htm

Jack

Jack is an ergonomics and human factors product that helps enterprises in various industries to improve the ergonomics of product designs and workplace tasks. This software enables users to position biomechanically accurate digital humans of various sizes in virtual environments, assign them tasks and analyze their performance. Jack (and Jill) digital humans can tell engineers what they can see and reach, how comfortable they are, when and why they're getting hurt, when they're getting tired and other important ergonomics information. Jack can also be integrated with other modeling applications, such as the Crew Station Design Tool, to optimize performance analysis.

Information about Jack retrieved December 31, 2007, from:

http://www.eds.com/products/plm/efactory/jack/

JASS (Job Assessment Software System)

JASS is a computer based survey tool used to identify and rate the level of skills and abilities necessary to perform jobs and job duties. Survey participants provide a rating value for a taxonomy of 50 generic cognitive skills and perceptual-motor abilities. JASS is useful in determining the skills and abilities required to operate and maintain a current system and comparing those required from a proposed new system acquisition. The skills and abilities of the proposed new system can also be compared to the available population of operators and maintainers. Information on excessive or unique skill demands can be used to influence system design early in the acquisition cycle.

Information about JASS retrieved December 31, 2007, from:

http://dtica.dtic.mil/ddsm/srch/ddsm130.html
http://www.dtic.mil/matris/ddsm/srch/ddsm0211.html

KARMA (Knowledge-based Augmented Reality for Maintenance Assistance)

A procedure guiding tool called KARMA (Knowledge-based Augmented Reality for Maintenance Assistance) is currently being tested at Columbia University. Graphics and text are overlaid on the surrounding world to explain how to operate, maintain, or repair equipment. The overlays

are accomplished using a transparent head mounted display (HMD). The KARMA team stresses that until overlaid explanatory graphics can be designed "on-the-fly" this technology will not be cost-effective compared to current techniques for offering technical information, however. KARMA can be used for procedure development by allowing the designer to overlay aspects of the user environment, graphically, so that the goals of the design can be applied to the environment in which it will be used before the development of the system.

Information about KARMA retrieved December 31, 2007, from:

http://www1.cs.columbia.edu/graphics/projects/karma/karma.html

KeyGhost

KeyGhost markets a USB plug-in device that monitors keystrokes. This device can be transferred from computer to computer so that real time monitoring as well as latent monitoring can be conducted.

Information about KeyGhost retrieved December 31, 2007, from:

KeyGhost, Ltd., (2000). KeyGhost - the Hardware Keylogger, http://www.keyghost.com/hardware-keylogger.htm .

Keystroke Logging

Key Loggers monitor the user's key strokes. Key loggers track every keystroke typed on a keyboard to determine every little movement that the user makes. This technology is easy to obtain. Just type in Keystroke Logging into Google, and more than 153,000 results are displayed. KeyLoggers are very useful in determining error sources in computer systems

Information about Keystroke Logging retrieved December 31, 2007, from:

Wikipedia contributors (2005). Keystroke logging. Wikipedia, The Free Encyclopedia. http://en.wikipedia.org/w/index.php?title=Keystroke_logging&oldid=33468557

LearnSafe

In Sweden, a whole system approach to organizational learning was taken in, LearnSafe, a project funded by the Nuclear Fission Safety part of the 5th Framework Programme of the European Union. The main objective of this project was to create tools and methods for supporting processes of organizational learning at several NPPs in five countries. Organizational learning is a facet of Knowledge Management which addresses the danger of the rapid process change present in the nuclear industry because as change is occurring so quickly, minor problems become catalysts for larger problems that can have catastrophic consequences. In the final technical report, the LearnSafe project identifies tools and methods for managing change and a list of hindrances and facilitators to organizational learning. While these tools and methods are not an evaluation method in and of themselves, they can be used as guidelines in developing evaluation methods.

For more information see:

Wahlstrom, B., Wilpert, B., Cox, S., Sola, R., Rollenhagen, C., (2002) Learning Organizations for Nuclear Safety. Paper presented at IEEE 7th Human Factors Meeting, Scottsdale, AZ.

LDRA Design Review

Design Review is a component of the LDRA product toolbox that performs dynamic systems design analysis. Embedded software systems do not always match their validated design after implementation. This can result in software or systems failure which can be fatal in a safety critical system. Design Review analyzes system's software performance at run time to expose the software's conformance or non-conformance to the validated design. By reducing or eliminating defects before the system is brought on-line, costly systems failures are averted.

Information about LDRA Design retrieved December 31, 2007 from:

http://www.lrda.co.uk/designreview.asp

See also:

Binder, J., "Testing software: The new frontier", printed in Aerospace America, June 2005, p.30-31.

MABTA (Multiple Aspect Based Task Analysis)

MABTA addresses the issue of group work task analysis (tasks shared between users) and environmental interaction (context of use). It uses 'coordination theory' (Malone and Crowston, 1990) and 'activity theory'(Nardi, 1996) to incorporate context of use, and a Design Information Framework (DIF) to merge multiple user viewpoints. Activity theory relies on a more complex, social view of human interaction, beyond the commonly used stimulus-reaction approach in other methods. At present, the authors of this method acknowledge that a CASE tool is needed to handle the amount of data generated by the multiple models and environmental information contained in this approach.

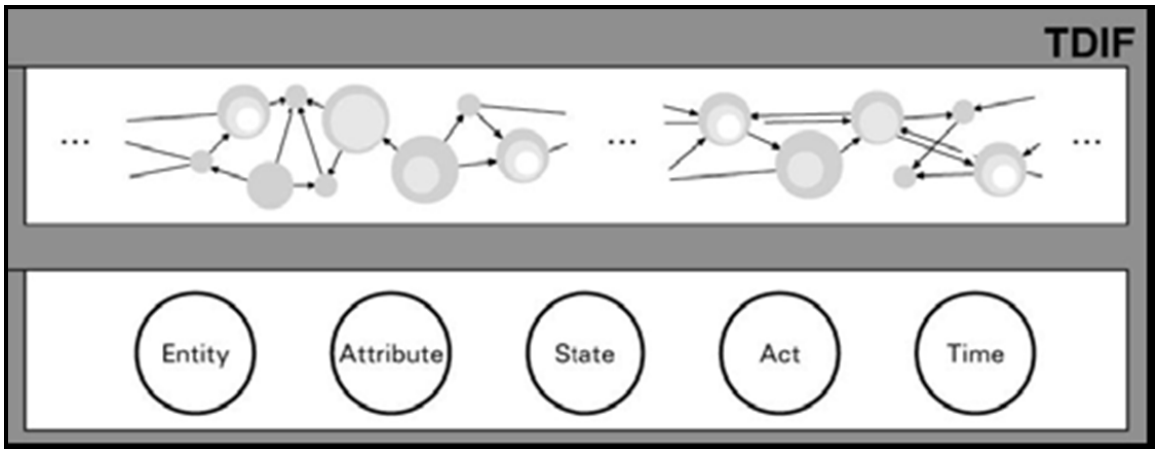

Figure A7 Elements of the Design Information Framework used by MABTA

Information about MABTA retrieved December 31, 2007, from:

Youn-Kyung Lim, Indiana University,
http://hcid.informatics.indiana.edu/research/default.asp?id=3

See also:

Malone, T. W., & Crowston, K. What is coordination theory and how can it help design cooperative work tools? Proceedings of the Conference on Computer-Supported Cooperative Work, Los Angeles, CA, October, 1990. (Reprinted in D. Marca & G. Bock (Eds.) Groupware: Software for Computer-Supported Cooperative Work, Los Alamitos, CA: IEEE Computer Society Press, 1992. Also reprinted in R. M. Baecker (Ed.), Readings in Groupware and Computer Supported Cooperative Work, San Mateo, CA: Morgan Kaufmann Publishers, 1993.)).

B. Nardi, Context and Consciousness: Activity Theory and Human-Computer Interaction, MIT Press, Cambridge, MA (1996).

ManneQuinBE

ManneQuinBE extends the ManneQuinPro product line of customized ergonomic technology. ManneQuinBE performs basic human factors analysis to ensure the highest level of comfort, safety and efficiency for the humans who will work, live and play in any newly designed or modified space. The software allows designers to incorporate human figures, even those with specific physical challenges, into every design-easily, accurately and inexpensively. ManneQuinBE places customized male and female mannequins of all ages in the design and animates them to explore all possible human ranges of motion and vision, showing the designer exactly how the human will "fit" and "see" the space.

Information about ManeQuinBE retrieved December 31, 2007, from:

http://www.nexgenergo.com/ergonomics/mqbe.html

mCheck

Paraphrasing the manufacturers website (www.systemautomation.com), mCheck is a customizable, mobile inspection system that allows inspectors to mark checklist items, record violations, document inspections activities, capture electronic signatures and print inspection reports using a laptop, tablet, or PDA. mCheck includes a "wizard" setup approach allowing all requirements to be custom tailored without any programming. In response to these templates, mCheck provides standard features for accurately capturing data. These controls include check boxes, radio buttons, dropdowns, numeric fields, text fields and free-form comment or signature fields. mCheck can also be configured to interface with an agency's existing office automation system or with the popular professional licensing solutions, License 2000® and MyLicense.

Information about mCheck retrieved December 31, 2007, from:

http://www.systemautomation.com/products_mcheck.htm

MIDA (Multi-modal Interface Design Advisor)

The Multi-modal Interface Design Advisor (MIDA) tool is an innovative method for providing multi-modal support across a wide variety of platforms for both government and commercial interests. MIDA represents an integrated approach to multi-modal interface design that examines the characteristics of the operator, the tasks the operator must perform, and the environment in which the resulting interface will be used. MIDA incorporates task network modeling to help identify resource conflicts and a comprehensive library (database) of multi-modal technologies and design guidance to generate recommendations for design.

The following figure shows the steps involved in using MIDA. The first step in a MIDA analysis is to identify as many characteristics of the potential operators (users) of the multi-modal workstation (and their work environment) as possible. The more characteristics that are identified, the more specific and accurate MIDA's final design recommendations will be. This is especially important in dynamic systems where decisions need to be made quickly or the successful completion of a task can affect the loss of life or equipment. MIDA also allows designers to set some restrictions of technologies that will be available or not due to availability or monetary constraints.

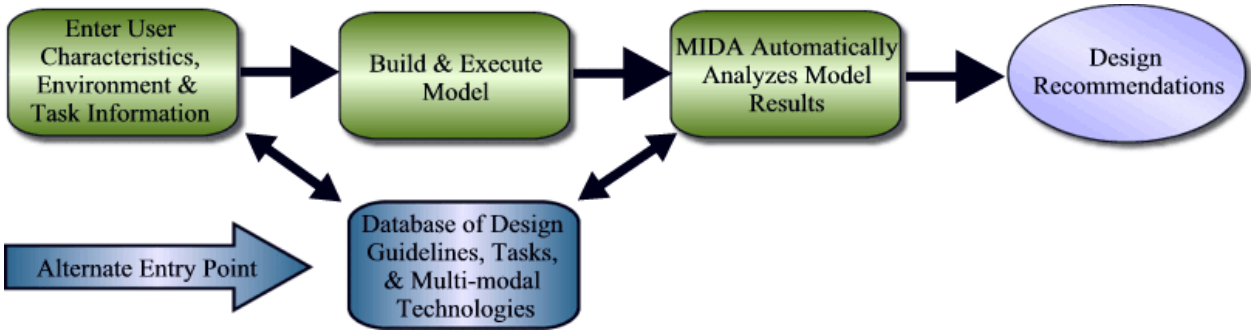

Figure A8 Steps in performing an interface analysis using MIDA

The second step in a MIDA analysis is to map out the job to be performed using the multi-modal interface; including the tasks the users must perform to accomplish their work and the workflow and timing requirements. The more information that is entered for each task, the more specific and accurate MIDA's final design recommendations will be. Workload information can also be entered for each task which will help to determine which of a user's perceptual channels are getting overloaded.

The third step in a MIDA analysis is to build and execute a task network model of the job performed by the user in order to assess his workload using the multi-modal interface. When the Task Network Model option is selected, MIDA opens the simulation software Micro Saint Sharp. MIDA automatically builds a task network model in Micro Saint Sharp and enters the necessary code into the model. This code defines variables, how long it takes to perform a task, workload values, etc.

The functions and tasks entered in Step 2 are automatically placed in the task network model. Now it is left to the designer to sequence the functions and tasks in the model. After this is done,

the model is ready to be executed. When the simulation has completed, Micro Saint Sharp can be closed and the workload results and the design recommendations can be viewed in MIDA.

The model helps to determine times in the scenario when an operator's sensory channels are overloaded. The reports show which tasks interfere with each other, and based on this interference, make recommendations of how to design the system (changing the modality of an input or output) to reduce this interference. MIDA also includes libraries containing HF guidelines on which the recommendations are based and technologies that are available to the designer.

MIDA is currently being developed with funding from an extended Phase II Small Business Research Initiative (SBIR) from the U.S. Navy.

Information about MIDA retrieved December 31, 2007, from:

http://www.dodsbir.net/awardlist/abs022/navyabs022.htm Topic #Navy 02-160

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MIDAS (Man-Machine Integration Design and Analysis Systems)

The Man-Machine Integration Design and Analysis System (MIDAS) is a 3-D rapid prototyping human performance modeling and simulation environment. It facilitates the design, visualization, and computational evaluation of complex man-machine system concepts in simulated operational environments. It also combines graphical equipment prototyping, dynamic simulation, and human performance modeling with the aim to reduce design cycle time, support quantitative predictions of human-system effectiveness, and improve the design of crew stations and their associated operating procedures. The tool links a virtual human, comprised of a physical anthropometric character, to a computational cognitive structure that represents human capabilities and limitations. The cognitive component consists of a perceptual mechanism (visual and auditory), memory, a decision maker and a response selection architectural component. The complex interplay among bottom-up and top-down processes enables the emergence of unforeseen, and non-programmed behaviors. MIDAS outputs include dynamic visual representations of the simulation environment, timelines, task lists, cognitive loads along 6 resource channels, actual/perceived situation awareness, and human error vulnerability and human performance quality.

This integrated suite of software components aids analysts in applying human factors principles and human performance models to the design of complex human-machine systems. MIDAS was designed to be used at the early stages of conceptual design as an environment where designers can use computational representations of the crew station and operator, instead of hardware simulators. This allows the designers to discover problems and ask questions regarding the projected operator tasks, equipment and environment for advanced vehicles. The goal is for this environment to contain tools and models that will assist design engineers in the initial concept design of crew station development and to anticipate training requirements. The system will provide designers with predictive data on operability, levels of automation and function allocation, and to support further research on human performance models. The

designer can specify tasks and activities to be performed by the operators, functional and physical characteristics of the cockpit environment, and operator characteristics.

The MIDAS simulation system is based on models of simulated operators interacting with models of cockpit equipment, vehicles, terrain and other scenario objects. The actual mission scenario that results from running a simulated mission may be a combination of planned and contingent activities. The symbolic operator models include models of vision, attention and perception. A task-loading model computes resource loading and conflicts.

Information about MIDAS retrieved December 31, 2007, from:

http://caffeine.arc.nasa.gov/midas/index.html

http://human-factors.arc.nasa.gov/dev/www-midas/

MITes (Massachusetts Institute of Technology Environmental Sensors)

MITes evolved from a project done at MIT. This project produced a simple, small, and inexpensive sensor network technology that does not require batteries. The purpose of the MITes is to collect real time data about human activities within a system. MITes provide a "Stick and Stay" technology that allows one to stick MITes on an object that can communicate with a receiver to aid in activity recognition, gait defects, security systems, position tracking, context-aware computing, and human computer interfaces.

For more information see:

Tapia, E., Marmasse, N., Intille, S., Larson, K. (2004). MITes: Wireless Portable Sensors for Studying Behavior. In Proceedings of Extended Abstracts Ubicomp 2004: Ubiquitous Computing, 2004, Accessed online from http://web.media.mit.edu/~intille/papers-files/MunguiaTapiaETAL04.pdf

Motes

MOTES scatter a "smart dust" comprised of tiny remote sensor chips that collect data. MOTEs are comprised of small computers that monitor one or more tiny sensors which measure any number of environmental characteristics such as temperature, stress, vibration, noise, etc. Information collected by the computer is connected to the outside world through the use of a radio link. Motes are especially applicable in Human Performance monitoring and activity tracking. The small size of Motes allows them to be used in large quantities to form networks in which they communicate together. As a person performs various activities and moves from location to location, the Motes within the network can pass along the information about that person's activity.

For more information see:

Hoffman, T., (2003). Smart Dust: Mighty Motes for Medicine, Manufacturing, the Military, and More, ComputerWorld, March 24, 2003.

http://www.computerworld.com/mobiletopics/mobile/story/0,10801,79572,00.html,

MVTA (Multimedia Video Task Analysis)

MVTA (Multimedia Video Task Analysis) automates time and motion studies and ergonomic analysis of visually discerned activities using a novel graphical user interface. The software enables users to identify events interactively with the use of break points in the video record (identifying the start and end of an event). The video can be analyzed at any speed an in any sequence (real time, slow/fast motion or frame-by-frame in forward/reverse direction). MVTA produces time study reports and computes frequency of occurrence of each event as well as postural analysis.

Information about MVTA retrieved December 31, 2007, from:

http://www.nexgenergo.com/ergonomics/mvta.html

Nomad Expert Technician System

The Nomad Expert Technician System from Microvision is the first augmented reality device being marketed commercially for the auto industry technician. With this device, technicians can read the detailed service information and follow complex instructions directly at their point of task, heads-up and hands-free. The monocle is worn in front of the eye and reflects scanned laser light to the eye allowing mechanics to view car diagnostics and instructions superimposed on their field of vision.

Honda technicians who use this system are saving about 40% of the time spent working on engines. Surgeons have also tested a version of the system which gives them vital patient data, such as heart rate and blood pressure, as they operate.

Information about Nomad retrieved December 31, 2007, from:

http://www.microvision.com/nomadexpert/

Figure A10 Nomad Expert Technician System

NTMPS (Navy Training Management and Planning System)

Navy Training Management and Planning System (NTMPS), a Naval Education and Training Command (NETC) program, is the Navy's official enterprise training management system that serves as the backbone for comprehensive data analysis and report generation, encompassing all aspects of manpower, training, facilities, funding and personnel. NTMPS data is collected from more than 30 authoritative databases, integrated and then made accessible to approved users, using the latest business intelligence tools.

NTMPS can be useful in training design as the knowledge included in the databases provides the designer with the most current information and tools to incorporate in training design.

Information about NTMPS retrieved December 31, 2007, from:

http://www.ntmps.navy.mil
http://www.ntmps.navy.mil/Info/ETJWEB/index.htm

Object Oriented Approach to Requirements

The Object Oriented approach to requirements analysis is not an entirely "new" concept. However, it is fast becoming the most widely accepted approach. The Object Oriented approach views information systems as collections of interacting objects (whether human or machine), and places emphasis on object classification (type), the work (tasks) carried out by these objects, and the interactions required to complete that work. The Object Oriented approach to systems requirements analysis is based upon the following principles:

- A system is a collection of interacting objects
- Objects interact with people and with other objects
- Objects send and receive messages

Most object oriented analysis methods are based upon the Unified Modeling Language that was developed by the Rational Corporation (now a part of IBM). The Unified Modeling Language (UML) was presented to the OMG (Object Management Group) in response to a request for a standardized modeling technique. By establishing a standard for Object modeling, the OMG (a consortium of over 800 object oriented software vendors, developers, and organizations), accepted UML as a uniform standard to ensure that object oriented software developed remains standardized.

There are several types of UML diagrams or modeling technique currently used in systems analysis and design. Each of these modeling techniques describes aspects of the system from different perspectives. The Use Case Diagram is the only technique that focuses on how the system is used, and describes the system from the perspective of the user.

A use case diagram shows the various user roles and how those roles use the system. The use case is the activity that the system carries out, and the persons or components that use the system are called actors. The Use Case Diagram is represented in Figure A9.

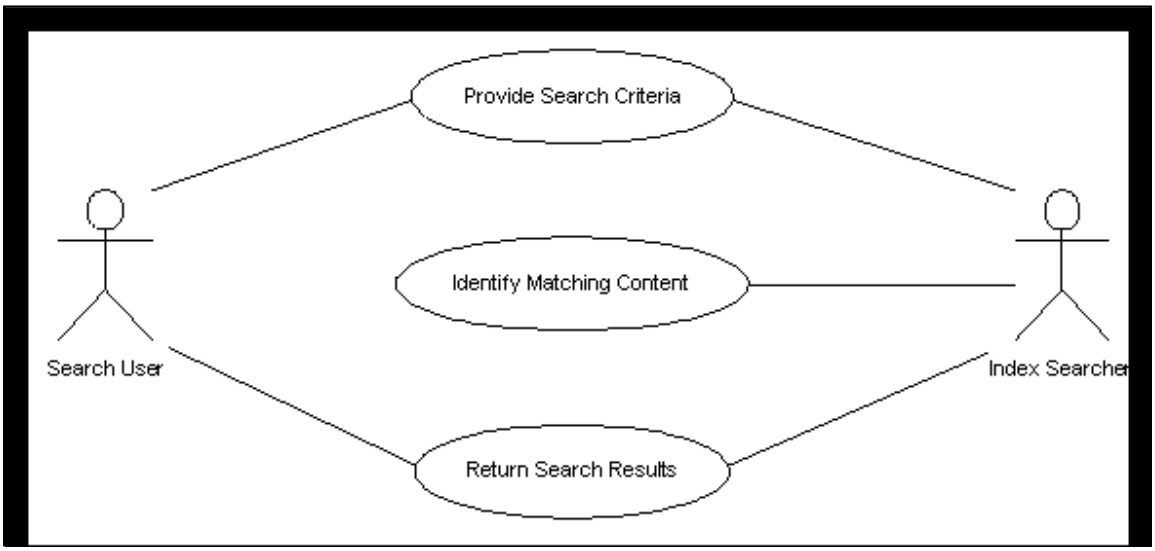

Figure A9 Use Case Diagram

The actors are represented by stick figures, use cases are represented by the ovals, and the lines illustrate the relationships between the actors and the use cases. The use case diagram is a top-level diagram that illustrates the interaction between users and the functional requirements of the system.

For more information see:

Satzinger, J., Jackson, R., & Burd, S., (2004). Systems Analysis and Design in a Changing World. Boston, MA., Thompson Course Technology.

Objectiver

Objectiver applies a goal based approach to requirements engineering that enables users to have a global overview of the system and a systematic link between all the models representing the system. Analysts have the possibility to draw diagrams and to define concepts (like goals, requirements, agent, entities, events, relationships, actions,...) and relationships to develop and analyze both functional and non functional requirements. Diagrams can be explained with text documents including references to concepts elicited in the diagrams. All these pieces of information can then be put together to generate a complete requirements document compliant with predefined standards.

Information about Objectiver retrieved December 31, 2007, from:

Cediti, http://www.objectiver.com/
Volere (2005). Requirements Tools. http://www.volere.co.uk/tools.htm . Last updated November 2005.

Participatory Design

Participatory design is a technique in which representative users provide continual feedback to designers as they develop preliminary prototypes in low-fidelity media (e.g., pencil and paper).

This method gives users an opportunity to interact with their suggestions for the product before those suggestions are codified into a program. Often these interactions lead to practical improvements on user suggestions. Such improvements can result in a product that better fits the need underlying the user's suggestion, as opposed to merely following the suggestion itself. (Extracted directly from http://www.ergolabs.com/participatory_design.htm)

Information about Participatory design retrieved December 31, 2007, from:

http://hci.stanford.edu/bds/14-p-partic.html
http://www.ergolabs.com/participatory_design.htm

See Also:

Douglas Schuler and Aki Namioka, (eds). Participatory Design: Principles and Practices. Hillsdale, NJ: Lawrence Erlbaum Associates, 1993.

On-line Help

On-line, context-sensitive help capabilities provide quick and responsive assistance to operators who are already trained. Rather than automatically generating an entire dictionary of all Help topics at once, which would overburden the user and be too time consuming, a context-sensitive capability can first provide Help information on only that portion of the software that is currently being used by the operator. Context-sensitive Help can include multi-layer Help (e.g., select "More Help" to progress from simple hints to a full explanation), commercial browser technology, and HTML technology which support multimedia Help capabilities. On-line Help may also include user manuals.

For more information see:

Weber, J. and Granor, T. (2004). Is the Help Helpful? : How to Create Online Help That Meets Your Users' Needs. Hentzenwerke Publishing.

Outcome-Driven Simulations

Considered a form of e-learning, outcome-driven simulations utilize Goal-Based Scenarios and serve as an alternative to learn-by-doing environments based on constructive simulations (Lockheed Martin Corporation, 1998). Under outcome-driven simulations, users adopt a role in a fictional scenario, and where the decisions and action that the user takes moves the scenario forward in time to new situations that are relevant to the pedagogical objectives (Gordon 2004). Once a user navigates through a scenario, training concludes with an after-action review which provides the user with an indication of the quality of the decisions they made during the scenario. Outcome-driven simulations can be used to train a wide variety of occupations and user types. Currently, the most typical skills that are targeted are those associated with personnel management, project management, customer relations, and sales engagements (Gordon 2004).

Outcom-Driven Simulation uses a "story-telling" methodology in which possible user experiences are organized into a branching storyline. This allows training designers to develop training programs that provide learners the opportunity to benefit from the knowledge sharing

and experience of others while also giving them the opportunity to learn the outcome of an alternate decision.

For more information see:

Gordon, A.S. (2004), Authoring Branching Storylines for Training Applications. Proceedings of the Sixth International Conference of the Learning Sciences (ICSL-04), Santa Monica, CA.

Lockheed Martin Corporation (1998) OneSAF testbed baseline assessment. Document ADST-II-CDRL-ONESAF-9800101, May 8, 1998. http://www.onesaf.org/publicotbdocs.html

Participatory Task Modeling

One drawback to modeling is that seldom is the modeler also the user of the system that is being modeled. As a result, perceptions about work performed form judgments that may or may not be accurate, and while usually discovered during the design verification and validation process, it is a constraint that can weigh heavily on project timing. Participatory Task Modeling (O'Neill, 2004) is an analysis and design technique that aims to overcome this challenge to modeling. In Participatory Task Modeling, data gathering, analysis, and modeling are integrated in an iterative process in which both users and developers discuss, share, and model "an emerging understanding of the users' roles, tasks and domains." (O'Neill) Once the current work situation is depicted accurately, the same shared process is performed to develop a model of the envisioned work situation.

For more information see:

O'Neill, E. and Johnson, P. 2004. Participatory task modeling: users and developers modeling users' tasks and domains. In Proceedings of the 3rd Annual Conference on Task Models and Diagrams/TAMODIA'2004 (Prague, Czech Republic, November 15 - 16, 2004).

PHRED (Plant-Human Review and Effectiveness Decision tool)

PHRED (the Plant-Human Review and Effectiveness Decision tool) is a discrete event simulation tool developed based on Micro Saint Sharp specifically for use in modeling NPPs and developed for the NRC. It automates many of the complexities of human performance modeling. PHRED allows NRC staff to design discrete-event simulation models and to obtain relevant data to assess significant human errors fairly quickly. It is designed to be reduce the effort and experience needed to generate models and useful information from those models.

For more information contact:

Alion Science and Technology
4949 Pearl E. Circle, Ste 300
Boulder, CO 80301

PROCEL (Procedures Electroniques)

PROCEL is a procedure-aiding system developed by Systemes Humains- Machines, Inc., a Canadian Human Factors Engineering company. PROCEL is a generic procedure-aiding

prototype that uses an open user-interface design coupled with a pen-based computer to provide:

- Simplified navigation.
- High degree of portability.
- Use of familiar interface metaphors.
- Integration with the internet, or with an intranet

It facilitates procedure and data exchange and configuration management. The communication facilities minimize the processing power and storage capacity that must be provided by the unit.

Information about PROCEL retrieved December 31, 2007, from:

http://www.shumac.qc.ca/Documents/procedureaiding.pdf

Rapid Prototyping

In manufacturing, rapid prototyping is a technology in which 3 Dimensional physical models are constructed from CAD designs or data. The use of rapid prototyping allows designers to create tangible models quicker and more efficiently than traditional prototyping methods. In systems design, the principles and the benefits are well aligned. Rapid prototyping in systems analysis and design is an interactive, iterative approach to design in which prototypes of the system are built and continually evaluated. Testing is performed on physical prototypes of the system as opposed to models, so designers and testers have the ability to evaluate human-system interaction in real time. Generally, rapid prototyping reduces the time to production and reduces cost.

Information about rapid prototyping retrieved December 31, 2007, from:

http://www.usabilitynet.org/tools/rapid.htm

http://www.personal.umich.edu/~jmargeru/prototyping/references.html

RFID (Radio Frequency Identification)

Radio Frequency Identification (RFID) is a tracking technology that is in widespread use in manufacturing and retail industries. Similar to bar coding, it can be used to track the movement of products and inventory as they move from point to point in the production or sales and inventory process. RFID is beneficial because it does not require line of sight, and the Chip that is imbedded in the RFID tag can hold a vast amount of information about the object it is attached to. RFID works with 4 main components, a tag that can be passive or active, a reader, an antenna, and software. A tag is an object that is to be tracked, and it communicates with the reader using the antenna. Information about the tag's movement is then passed to the application software.

The Department of Defense has mandated that as of January 2005, all inventory (pallets of low cost items and individual items costing $5000 or more), be fixed with RFID tags. RFID has also become the much publicized standard for warehousing and inventory for Wal-Mart, International Paper, Proctor and Gamble, and Gillette, to name a few. But warehousing and inventory are not the only applications for RFID technology. New Standard News has articles posted about

the use of RFID and the accompanying controversy in tracking humans, namely children, students, and immigrants.

Intel has conducted a vast amount of research into the use of RFID technology for Human Activity recognition and detection. They have also developed devices which are designed to track object use, which can also be adapted for interface use.

For more information see:

Capone, G., Costlow, D., Grenolbe, W., Novack, R. (2005). The RFID-Enabled Warehouse. White Paper published for SAP Community, 10/18/2005., Accessed online from http://sap.ittoolbox.com/documents/peer-publishing/the-rfidenabled-warehouse-3554 on December 29, 2005.

Komp, C. (2005). Electronic Tags Used to Track Immigrants. New Standard News online publication. http://newstandardnews.net/content/index.cfm/items/2324

Smith, J., Fishkin, K., Jiang, B., Mamishev, A., Philipose, M., Rea, A., Roy, S., and Sundara-Rajan, K. (2005). RFID-Based Techniques for Human-Activity Detection Communications of the ACM, September 2005, Vol. 48, No., 9.

Safework Pro

Safework Pro is a 3D computer model that incorporates anthropometrically correct mannequins into the specified physical environment. It enables analysis of see, reach and fit attributes, clothing effects, and postural and biomechanical analyses. It can also incorporate virtual reality technologies.

Information about Safework Pro retrieved December 31, 2007, from:

http://www.safework.com/safework_pro/sw_pro.html

SALT (Spatial Analysis Link Tool)

The Spatial Analysis Link Tool (SALT) is a tool for designing the physical relationships between simple objects in a space using link analysis. It provides tools for manually configuring objects and viewing their relationships in "real-time" and allows for the characterization of their relationships (links). It also provides automated recommendations for layout of the objects. The results of the analysis can then be transferred to a more detailed modeling/CAD tools.

For more information contact:

Matt Wilson - Sonalysts
(540) 663-9034
wilsonm@sonalysts.com

Owen Seely, HSI Engineer, Naval Surface Warfare Center
Dahlgren, VA
(540) 653-0782
Owen.seely@navy.mil

SAMMIE CAD

The SAMMIE system is a 3D Ergonomics Computer Aided Design tool that enables designers and engineers to produce working 3D models of workplaces and equipment and conduct ergonomics evaluations of these with any number of variable human-models. SAMMIE enables the evaluation of Fit, Reach, Vision, Postural Comfort and Mirrors (reflected glare) for the potential user population, most effectively at the concept or development stages of a design process, when it is still possible for designers to make major changes to the layout and form of a workplace.

SAMMIE offers the following:

- 3D analysis of fit, reach, vision and posture
- Reduced timescale
- Early input of ergonomics expertise
- Rapid interactive design
- Improved communication
- Cost effective ergonomics

Information about SAMMIE CAD retrieved December 31, 2007, from:

http://www.sammiecad.com/

SCADE (Safety Critical Application Development Environment)

The Design Review component of the SCADE development suite is a proof engine that enables designers to prove that a system's design is "safe" with respect to its requirements. In other words, the Design Verifier can be used to determine if the software design as implemented matches the design as validated, thus ensuring that a "software failure" will not cause the system to fail because of non-conformance.

Information on SCADE Design Review retrieved December 31, 2007 from:

http://www.esterel-technologies.com/products/scade-suite/design-verifier.html

Scenario Based Function Allocation

Traditional function allocation focuses on binary techniques (such as decision matrices) that strive to determine the best possible method for assigning functions or tasks to the major stakeholders that comprise a system - man or machine. While these methods are useful, they do not look at the larger picture and consider that some functions must occur concurrently, and optimal allocation may not be the same in every situation.

Scenario Based function allocation aims to take a holistic approach to function allocation by:

- Allowing decision makers to consider many alternative human-computer interaction methods
- Ensures that the attributes of the worker and the work environment are considered in making allocation decisions

- To highlight the organizational tradeoffs between suggested design options for different functions.

To perform Scenario Based function allocation, a small number of scenarios are developed to describe situations in which a new system might be used. Each scenario is then evaluated to identify a set of required functions. Subsets of these functions are developed to identify the candidates for total automation, and remaining functions are evaluated to develop possible design options for partial automation. Cost-benefit analyses are performed to rate the options. Partial automation options are selected using a two dimensional grid, and any tasks that appear to need further analyses are reevaluated separately. After each scenario has been evaluated, all are compared collectively. Areas where conflicts or contradictions exist indicate a potential need to apply dynamic allocation. As requirements change, scenarios can be revised and the process can be repeated using different scenario mixes.

For more information, see:

Dearden, A., Harison, M., and Wright, P. (2000). Allocation of function: scenarios, context and the economies of effort. International Journal of Human Computer Studies 52(2), pp. 289 - 318

ShipSHAPE (Ship System Human Systems Integration for Affordability and Performance Engineering)

ShipSHAPE is a set of automated processes, tools, and databases developed specifically to enable HSI analysts in the Navy and in the commercial ship building and maritime system arena to meet HSI requirements as contained in the Department of Defense (DoD) 5000 series, Secretary of the Navy (SECNAV) Instruction 5000.2B, Naval Sea Systems Command Instruction 3900.8, ASTM-1166 and ASTM-1337. The guiding principle behind the design of the ShipSHAPE software is that HSI analysts should have at their fingertips all of the guidance, instructions, processes, procedures, methods, tools, and data needed to conduct a timely and complete HSI effort. The elements of the ShipSHAPE system are: the HFE process for ships, automated HFE tools, and data bases of HSI standards and results of HSI analyses for ship systems.

The tools included in the ShipSHAPE family are: Integrated Mission/function Analysis and scenario Generation (IMAGE), Role of Man and Automation Tool (ROMAN), ASSESS, and Integrated Non-Development Item Selection/Assessment Tool (INDI.)

Information about ShipSHAPE retrieved December31, 2005, from:

http://carlow.com/hsitools.html

SkillsNET

SkillsNET provides a suite of tools for capturing job specific data for tasks, tools, abilities, skills, and unique knowledge required for exemplary performance of jobs. User can build job/skill profiles, determine precision learning targets, generate workforce development reports, and use numerous data mining tools for its National SkillObjects Library which includes data for over 1,300 key industry occupations.

The data is initially gathered from high performing job incumbents. Tools are also provided for analyzing and utilizing the data in the areas of:

- Career Path for Job Families
- Skills Inventory
- Job-Specific Online Interview Capability
- Workforce Capacity
- Curriculum Development and/or Individual Development Planning
- Performance Assessment
- Job Scenario Interview Capability
- Job Family Task Analysis

The Navy is using SkillsNET as to drive all training, education and proficiency requirements for every sailor in the navy community, both officer and enlisted.

Information about SkillsNET retrieved December 31, 2007, from:

http://www.skillsnet.biz/main.htm
http://www.skillsnet.com/

Smart-Its

Smart-Its are small context aware computers which use wireless technology to make the objects they are imbedded in, intelligent objects. They have the ability to make a bottle of wine smart enough to know if its cap has been put on correctly, an inform users of incorrect storage. Smart-Its can track how a human is using those applications, and provide warning systems for incorrect usage. Smart-Its can also be used as a valuable evaluation tool in monitoring human performance and activities and to gather data for the design and analysis of human computer interaction.

For more information see:

Gellerson, H., Schmidt, A., Beigl, M. (2002). Multi-Sensor Context-Awareness in Mobile Devices and Smart Artifacts. In Mobile Networks and Applications, Vol.7, Issue 5, October 2002.

Retrieved December 31, 2007, from:

http://web.media.mit.edu/~intille/papers-files/MunguiaTapiaETAL04.pdf

Soar

Soar is a unified architecture for developing intelligent systems. That is, Soar provides the fixed computational structures in which knowledge can be encoded and used to produce action in pursuit of goals. In many ways, it is like a programming language, albeit a specialized one. It differs from other programming languages in that it has embedded in it a specific theory of the appropriate basic fundamentals of reasoning, learning, planning, and other capabilities that we hypothesize are necessary for intelligent behavior. Soar is not an attempt to create a general purpose programming language.

Information about SOAR retrieved May 30, 2008 from:

http://sitemaker.umich.edu/soar

SoftSecurity

SoftSecurity offers professional computer monitoring software that utilizes a variety of technologies to monitor computer activity.

Information about SoftSecurity retrieved December 31, 2007, from:

Raytown Corporation, LLC. (2005), Professional Monitoring and Surveillance Software, http://www.softsecurity.com/

Software Reflexion

Frequently, when a system is designed, after requirements changes are made, and the software is designed and validated, the design as it is implemented varies greatly from the original design. Structural errors that contribute to these variances often slip through the cracks during the verification and validation process. Software reflexion is a method that is used to ensure that these errors do not slip through the cracks. Software reflexion compares high level models of the system to source models to determine differences and similarities. The analyst then reviews the results and makes adjustments to perform further software reflexion. This process can them be completed multiple times until all variances are resolved.

For more information, see:

Murphy, Notkin, and Sullivan. Software Reflexion Models: Bridging the Gap Between Design and Implementation. IEEE Transactions on Software Engineering, April 2001

TacWISE (Tactical Warfare Instructional Support Environment)

Originally developed for the US Navy, the Tactical Warfare Instructional Support Environment (TacWISE) is a training support tool designed to support the collection, integration, evaluation, and analysis of performance data in dynamic, multi-platform (whether ship, sub, land, or air-based) training environments. Its general purpose user interface and evaluation tool authoring capability make it adaptable for application to evaluating and analyzing performance on any type of complex training or operational activity. For large multi-platform exercises, the tool supports multiple networked evaluators concurrently and collaboratively evaluating different participants in the same exercise.

For more information, see:

Carolan, T., Mihal, J.,Jr, Little, T., Radtke, P., Collaborative Performance Evaluation in Multi Platform Team Training Exercises. Proceedings Interservice/Industry Training, Simulation, and Education Conference, 2005.

TaskArchitect

TaskArchitect is a commercial product from a company of the same name in Ottawa, Canada. TaskArchitect is a task analysis support tool, focused on the Hierarchical Task Analysis (HTA)method. The developers claim the tool "spans the processes from data collection to evaluation, with exporting to tools used for modeling and simulation." (Stuart, 2004). This method breaks human actions into tasks which are further decomposed into subtasks that provide increasing detail about the human actions.

Information about TaskArchitect retrieved December 31, 2007, from:

http://www.taskarchitect.com/
TaskArchitect, Inc., Jon Stuart,

TAWL (Task Analysis Workload)

TAWL uses task analysis information to develop operator workload prediction models, i.e., estimates of the workload associated with the cognitive, psychomotor and sensory components of individual and concurrent operator tasks. TAWL can be used with a variety of databases, such as the TAWL Operation Simulation System (TOSS). (TOSS is a database for aircraft which includes the UH60, AH64, CH47, MH47, and MH60.) With the TOSS database, TAWL can be used to determine the optimal system design or configuration for a mission based on workload considerations, develop models of two or more systems to identify the systems or configurations with higher workload and evaluate a system's manning and training requirements. The TAWL output consists of workload metrics (number of overload conditions, number of component overloads and overload density) for segments and crewmembers, summary of subsystem overloads and task listings. Analyses can be made for up to four crewmembers. The output from TAWL can be used to identify mission time periods, components, crewmembers and subsystems with high workload. This information can be used in the system design process, e.g., to make adjustments in the distribution of tasks during the mission to equalize workload over time and over crewmembers or to make adjustments in the nature of tasks.

Information about TAWL retrieved December 31, 2007, from:

http://www.dtic.mil/matris/ddsm/srch/ddsm0047.html
http://dtica.dtic.mil/ddsm/srch/ddsm15.html

TDFA (Top Down Function Analysis)

TDFA is a set of software tools and associated methodologies for performing top-down-function-analysis. The core of toolset is a relational database with user interface forms created using Microsoft Access. The database allows analysts to decompose functions, while also associating any number of attributes to the functions, such as time durations, information requirements, information sources, high driver elements and other related data essential to performing a proper TDFA. The database can be queried and searched to retrieve specific information regarding a certain function and/or event, thus facilitating multi-level analysis more effectively. The toolset also enables the generation of pre-formatted reports on specific functions, events, or phases of the mission or TDFA analysis.

For more information, see:

Bardine, D., Goff, U., and Wilson, M. TDFA Methodology and Tools. Presented at Human Systems Integration Symposium, Tysons Corner, VA, 2003.

Trigger Analysis

Trigger analysis is intended as a supplement to other decompositional task analysis methods (e.g. Hierarchical Task Analysis). It is concerned with discovering what causes a subtask to begin or end. Interruptions, delays, and shared work are often the cause of unexpected operator error. Trigger analysis helps to uncover these situations in the planning stage.

Information about Trigger Analysis retrieved December 31, 2007, from:

http://www.comp.lancs.ac.uk/computing/users/dixa/papers/triggers2002/TA-trigger-draft.pdf
Alan Dix, Lancaster University,

User-Centered Design (UCD)

User-Centered Design (UCD) is an approach to development that puts users at the center of the process. Some common UCD methods include focus-groups, usability testing, card sorting, participatory design, questionnaires, and interviews. UCD has become standard practice in software development worldwide (ISO 13407:1999 Human-centred design processes for interactive systems).

For more information see:

Mao, J., Vredenburg, K., Smith, P. W., and Carey, T. 2005. The state of user-centered design practice. Communications pf the ACM 48, 3 (Mar. 2005), 105-109.

ISO 13407. (1999) Human-centred design processes for interactive systems. International Organization for Standardization

Virtual Environment (VE) Training

Virtual Environment (VE) training relies on virtual simulations to provide a means for personnel to frequently and repetitively train in a realistic environment that is created inside a virtual simulation room. Studies evaluating Virtual Environment (VE) training have found that VE training can be effectively used as a training tool for improving decision-making, situation awareness, communication, and coordination skills. VE, especially when used in conjunction with realistic exercises, can play a major role in enhancing the training of personnel (Pleban & Salvetti 2003). A virtual training system can be particularly useful for "walk-level" and sustainment training (Pleban et al., 2001).
Virtual training not only provides the capability to immerse personnel in a realistic environment but this training can be accomplished without risking the safety of personnel, the safety of the NPP, disrupting normal plant operations, breaking expensive equipment, or potentially negatively impacting the environment.

Research has also shown that VE training has been successfully used to improve and enhance route knowledge within buildings (Witmer, Bailey, Knerr, & Parsons, 1996). VE training for

building navigation could be important for NPP personnel in an emergency where they may experience high stress levels and would otherwise suffer from poor situational awareness. As good as VE training has been shown to be, its initial implementation can be expensive, and it should not be a complete replacement for real-world training. However when used in conjunction with real-world training, or for refresher training, VE training is a powerful tool.

For more information see:

Pleban, R.J., Eakin, D.E., Salter, M.S., & Matthews, M.D. (2001). Training and Assessment of Decision-Making Skills in Virtual Environments (Research Report 1767). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences.

Pleban, R.J., Salvetti, J. (2003). Using Virtual Environments for Conducting Small Unit Dismounted Mission Rehearsals (Research Report 1806). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences.

Witmer, B.G., Bailey, J.H., Knerr, B.W., & Parsons, K.C. (1996). Virtual spaces and real world places: Transfer of route knowledge. International Journal of Human-Computer Studies, 45, 413-428.

Virtual Reality Technology

The term Virtual Reality (VR) initially referred to immersive systems, but today VR is also being used for semi-immersive systems like large screen projections (with or without stereo) or table projection systems. Even non-immersive systems, like monitor-based viewing of three-dimensional objects, are called VR systems. The rapid development of the World Wide Web has created additional versions of virtual reality with VRML, the Virtual Reality Modeling Language.

Using virtual reality to produce realistic prototypes that can be tested by experts will reduce the costs of developing finished products. Physical prototypes can be expensive to develop and change, but virtual prototypes can be changed quickly and inexpensively. The traditional design tools of manufacturing, CAD and CAM, can be significantly extended through VR. Using VR techniques, a complete "walk-through" of a design can be used to give an environment-like feel.

Information about Virtual Reality Technology retrieved December 31, 2007, from:

http://dmoz.org/Computers/Virtual_Reality/
http://www.itl.nist.gov/iaui/ovrt/hotvr.html

Web Training Technologies

Conducting trainings via the internet (relying on web technologies) is gaining increasing acceptance and popularity. Through web technologies personnel can watch lectures at their desk, in a conference room, a classroom, or at home; at any time. Another advantage of web technology is the ability to record a web session for later use. This capability provides a tremendous amount of flexibility in terms of delivery time and in the structuring of content (Kapp et al 2004). If web postings are utilized, ensure that the postings are maintained (e.g., they are periodically reviewed and deleted when information is out of date).

For more information see:

Kapp, K.M., Nicholson, M. Kind, T. (2004) Making the Most of Virtual Classrooms and Self-Paced Presentations- Guidelines for Rapid E-Learning. Macromedia, Inc.

WinCrew

WinCrew is a task and workload analysis tool. It predicts system performance as a function of human performance. It models behaviors in response to workload levels which may affect performance. WinCrew predicts and assesses changes in system performance as a result of varying function allocation, number of operators or crew, level of automation, task design, mode of information presentation, and response to high workload. The system is represented in two different ways:

- Users define the interfaces (controls and displays) that are used to perform tasks. The user then ties these interfaces to the resources (visual, cognitive, psychomotor, speech, and auditory) and defines how the resource/interface pairs are used.
- Users can represent the system using variables or by assigning tasks to systems.

Through iterative use, determine high drivers affecting human and system performance. This data can then be used to conduct statistical analyses testing such as sensitivity analysis. WinCrew has been used to investigate options for reduced manning, effects of different levels of automation, and workload imposed on human operators by system design concepts.

Information about WinCrew retrieved December 31, 2007, from:

http://www.manningaffordability.com/s&tweb/Demo/Demo_Abstracts/WinCrew.PDF

See also:

Archer, R. and Lockett, J. (1997) WinCrew: A tool for analyzing performance, mental workload and function allocation among operators; in, Proceedings of ALLFN 97, Revisiting the allocation of function issues, Vol. II, pp157-165, IEA Press.

WISP (Wireless Identification and Sensing Platform)

WISP is a Radio Frequency Identification (RFID) reader to track hand movements, but it is not a wearable device. It is more appropriate for more casual settings that require simple activity detection.

For more information see:

Smith, J., Fishkin, K., Jiang, B., Mamishev, A., Philipose, M., Rea, A., Roy, S., and Sundara-Rajan, K. (2005). RFID-Based Techniques for Human-Activity Detection Communications of the ACM, September 2005, Vol. 48, No., 9.

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APPENDIX B

Applicability of Methods and Tools to NUREG-0711 Review Element Cross Reference Table

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Applicability of Methods and Tools to NUREG-0711 Review Element Cross Reference Table

Tool	Operating Experience Review 3	Functional Requirements Analysis & Function Allocation 4	Task Analysis 5	Staffing & Qualification 6	Human - System Interface Design 8	Procedure Development 9	Training Program Development 10	Human Factors Verification and Validation 11	Design Implementation 12	Human Performance Monitoring 13
ACTA			X				X		X	
ACT-R					X					
ADVISOR							X			
AIM							X			
Analyst Pro		X								
ATEAMS							X			
Augmented Cognition						X		X	X	
Augmented Reality						X		X	X	
Business Process Modeling		X	X							
C3TRACE		X		X						
CARE		X								
Case Based Reasoning	X									
CASHE PVS					X				X	
CCAB				X						
CMS						X				
Cognitive Archeology			X						X	
Collaboration Tools										

Applicability of Methods and Tools to NUREG-0711 Review Element Cross Reference Table

Tool	3 Operating Experience Review	4 Functional Requirements Analysis & Function Allocation	5 Task Analysis	6 Staffing & Qualification	8 Human - System Interface Design	9 Procedure Development	10 Training Program Development	11 Human Factors Verification and Validation	12 Design Implementation	13 Human Performance Monitoring
Cognitive Systems Design										
Cognitive Task			X					X		
Cognitive Work Analysis		X								
Communities of Practice	X									
Computer Vision										X
CORE		X						X	X	
CREATE								X	X	
CSDT					X			X	X	
Data Flow Diagrams		X								
DELMIA HUMAN					X			X		
DOE Lessons Learned	X									
DOORS		X						X	X	
DUTCH			X							
EasyRM		X								
ECAT			X		X			X	X	
Ecological Interface Design					X					
ELECTRONUCLEAR	X									

Applicability of Methods and Tools to NUREG-0711 Review Element Cross Reference Table

Tool	Operating Experience Review	Functional Requirements Analysis & Function Allocation	Task Analysis	Staffing & Qualification	Human - System Interface Design	Procedure Development	Training Program Development	Human Factors Verification and Validation	Design Implementation	Human Performance Monitoring
	3	4	5	6	8	9	10	11	12	13
Embedded Training							X		X	
Entity Relationship Diagram		X								
Envision/Ergo					X			X		
EPIC					X					
EPRI SHP Program	X									
ErgoMaster					X			X	X	
FAST				X						
Foresight		X								
HCDA		X								
HFE-AT					X				X	
iBracelet										X
IBM Rational Clear Case and Clear Quest		X								
ICS-CTA			X		X				X	
IETM						X				
iGlove										X
IMPRINT		X	X	X				X	X	

Applicability of Methods and Tools to NUREG-0711 Review Element Cross Reference Table

Tool	3 Operating Experience Review	4 Functional Requirements Analysis & Function Allocation	5 Task Analysis	6 Staffing & Qualification	8 Human - System Interface Design	9 Procedure Development	10 Training Program Development	11 Human Factors Verification and Validation	12 Design Implementation	13 Human Performance Monitoring
Information Engineering		X								
IPME			X		X			X	X	
IRqAR		X						X	X	
ISMAT				X						
Isolde: U2T			X						X	
JACK					X					
JASS				X						
KARMA						X			X	
KeyGhost										X
Keystroke Logging										X
LearnSafe	X									
Link Analysis	X									
LRDA Design Review									X	
MABTA			X	X						
ManneQuinBE					X			X	X	
mCheck								X	X	
MIDA					X					

Applicability of Methods and Tools to NUREG-0711 Review Element Cross Reference Table

Tool	3 Operating Experience Review	4 Functional Requirements Analysis & Function Allocation	5 Task Analysis	6 Staffing & Qualification	8 Human - System Interface Design	9 Procedure Development	10 Training Program Development	11 Human Factors Verification and Validation	12 Design Implementation	13 Human Performance Monitoring
MIDAS					X					
MITes										X
Motes										X
MVTA			X						X	X
Nomad						X			X	
NTMPS							X			
Object Oriented Requirements		X								
Objectiver		X								
On-line Help							X			
Outcome-Driven Simulations							X			
Participatory Design										
Participatory Task Modeling			X						X	
PHRED		X	X	X				X	X	
PROCEL						X				
Rapid Prototyping					X					
RFID										X

Applicability of Methods and Tools to NUREG-0711 Review Element Cross Reference Table

Tool	Operating Experience Review 3	Functional Requirements Analysis & Function Allocation 4	Task Analysis 5	Staffing & Qualification 6	Human - System Interface Design 8	Procedure Development 9	Training Program Development 10	Human Factors Verification and Validation 11	Design Implementation 12	Human Performance Monitoring 13
Safework Pro					X			X	X	
SAGAT			X	X					X	
SALT			X						X	
SAMMIE CAD					X			X	X	
SCADE Design Verifier									X	
ShipSHAPE		X	X	X						
SkillsNet			X	X					X	
Smart-Its										X
SOAR					X					
SoftSecurity										X
Software Reflexion									X	
TacWISE							X			
TaskArchitect			X						X	
TAWL			X						X	
TDFA		X								
Trigger Analysis			X							
UCD										

Applicability of Methods and Tools to NUREG-0711 Review Element Cross Reference Table

Tool	3 Operating Experience Review	4 Functional Requirements Analysis & Function Allocation	5 Task Analysis	6 Staffing & Qualification	8 Human - System Interface Design	9 Procedure Development	10 Training Program Development	11 Human Factors Verification and Validation	12 Design Implementation	13 Human Performance Monitoring
Virtual Environment Training							X			
Virtual Reality Technology								X	X	
Web Training Technologies							X			
WinCrew			X	X					X	
WISP										X