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SOFTWARE SUPPORT FOR SHARING AND TRACKING HUMAN FACTORS ISSUES DURING SHIP DESIGN

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SUMMARY

Integration of Human Factors (HF) into ship design requires considering the impact of design features on the crew. HF in ship design must take into account such features as access and egress; space requirements for habitability; lines of sight to equipment and operators; reach to equipment, and human: machine interaction to name just a few. The Directorate of Maritime Ship Support (DMSS) in the Canadian Department of National Defence provides life cycle support for HF in Canadian warships including the review of ship compartment designs for compliance with good HF practice.

The *Human Factors Engineering – Intelligent Computer-Aided Drafting and Design* (HFE-ICADD) software was developed to support application of HF in the design or modification of Canadian warships to:

- Act as a central record for the HF plan and design criteria determined during concept development and preliminary design, and implemented during contracted design.
- Capture operational experience in the form of task analysis data, and design experience in the form of case-based reasoning.
- Track iterations of drawings, compartment specifications, or a debate on a HF concern.
- Provide hard/software flexibility to support use across several sites (DND and contractors).

This project integrated custom designed, and off the shelf software products to facilitate sharing of design criteria and review decisions over the life cycle of a vessel. HFE-ICADD software has potential for use in any collaborative design environment where task and design review data and design decisions need to be shared among project personnel.

AUTHORS' BIOGRAPHIES

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Philippe Davidson is the President of Protogon Incorporated. Trained as an architect, he worked on several artificial intelligence research projects at the Canadian National Research Council. Since leaving the NRC, he has specialized in the application of artificial intelligence to CADD systems to enhance their integration into the design process. Projects include design task advisory systems, jet engine health monitoring, medical expert systems, and industrial automation.

Bob Webb is Principal Consultant for Human*systems* Incorporated. Human*systems* has worked in different Human Factors aspects of the development cycle for almost twenty years. Bob's previous experience includes the application of human factors to bridge operations during ice breaking in the Arctic, fatigue and marine watch-keeping, naval and army command and control, and sonar display systems, as well as other development or procurement related projects for the Canadian Defence Department and industrial clients.

Eric Coutu holds the positions of Human Factors Specialist and of Export Manager (Asia) at Safework (2000) Inc He is responsible for ergonomics studies in the automotive, aerospace, medical, defence, and textile industries. His project experience includes: Visual Requirements for Canadian Coast Guard icebreakers (Transport Canada); Ferry Wheelhouse Design (Quebec's Society of Ferries); Ergonomic Specifications for Bus Drivers and Passengers (Canada Urban Transit Association), Aircraft Design Support (Samsung Aerospace), Car Design Aid (Hyundai). These projects supported development of the SAFEWORK® tools that are now part of HFE-ICADD software.

1 INTRODUCTION

Human Factors literature related to ship design and operation covers a wide range of topics: automation, manning, bridge layout, control center layout, operator: interface design; helmsman behaviour, personnel traffic including stairway and ladder design, accommodations, manual-materials handling, safety, watch-keeping, etc. While research is needed to resolve problems associated with many of these factors, much information already exists to guide ship designers when dealing with these topics. Guidance to designers is provided by international standards such as those by the International Standards Organisation (e.g. ISO 8466 - Ship's Bridge Layout and Associated Equipment - Requirements and Guidelines) or the seven NATO Allied Naval Engineering Publications on human factors/ ergonomics.

Other information is provided by national standards such as the US ASTM F-1166-94 Standard Practice for Human Engineering Design for Marine Systems, Equipment and Facilities. In many cases there also exist codes of practice developed by ship operators on the basis of experience. Thus the integration of Human Factors (HF) into ship design involves consideration of the guidance provided by many different sources of information, including the practical experience of users and lessons learned from operating specific classes of ship.

In the Canadian Department of National Defence (DND), the responsibility for the application of HF principles in the design and life-cycle support of ship systems rests with the Directorate of Maritime Ship Support (DMSS). Those responsibilities include the specification of requirements for new or updated designs and the review of proposed designs for ship compartments for compliance with good human factors practice.

During major development or acquisition projects the personnel resources of DMSS 2-6 (the DND group responsible for HF aspects of ship design) are often strained by the volume of information, particularly in the form of drawings, to be assessed, and by sometimes competing demands from various project offices.

To assist DMSS 2-6 with this problem the Defence and Civil Institute of Environmental Medicine (DCIEM), the human factors research agency in DND, offered to DMSS 2-6 the use of some human factors tools that were being developed for application in aircraft systems development. DMSS concluded that these tools were not suitable for the range of problems they tackled during ship design and development and during the subsequent life-cycle support. Therefore, in 1992, DCIEM contracted out a requirements and feasibility study (1) of DMSS needs for human factors tools that lead to the subsequent development of the prototype software described in this paper.

2 ESTABLISHING THE REQUIREMENT FOR HFE-ICADD

This project adopted a user-centered, iterative design process The first step was to identify the personnel groups involved with HF in the overall design cycle. Then we conducted interviews to establish the responsibilities of such groups in the ship design cycle, their current approach to accomplishing these responsibilities, their concerns with the process as it stood, and their functional needs for HF support.

Within DND, DMSS usually exercises the responsibility for designing and modifying naval vessels by contracting out and then monitoring the work of contractors. DMSS is organized as a matrix of specialist cells. DMSS 2-6 is one cell among several groups of cells and is responsible for evaluation of HF aspects of ship designs. DMSS responds to naval operational requirements from the, then, Directorate of Naval Requirements (DNR). Contracting naval architects are assigned specific design responsibilities. Extensive liaison may be required, depending on the stage of the design cycle. Although there was a trend towards standardization of computer support systems, at the time that this project started, different groups had access to different systems.

Based on the matrix organizational structure, interviews and briefings were conducted with representatives of several different potential user groups of any HF software support system. User groups interviewed included DNR, DMSS 2-6, a cross section of specialists from other DMSS technical cells, and contractors (such as naval architects) with contract design experience for naval vessels with DND. Each stage in the design cycle was considered: namely concept exploration and feasibility, preliminary and contract design, detailed design, construction and acceptance trials.

In conjunction with the interview process, the project team also reviewed:

- Naval HF guidelines used to generate requirements for shipboard space design.
- HF software design support packages on the market at the time.
- Design review documents from previous naval construction projects.
- HF design and contract documents from previous naval construction projects.

These procedures provided the project team a comprehensive over view of the various user groups for HF, their technical and operational experience, and their needs for HF support, as well as events impacting on the quality of HF in the design cycle of naval vessels for DND.

For example, technical or operational specialists often made decisions early in the design cycle with limited insight into the downstream implications for HF. This carried the implication that early HF support could have a disproportionately beneficial effect on the subsequent HF review process and the speed and quality of the overall design outcome. Other points were that HF reviews during the development process, like all others, needed to be carried out within a tight time frame by both DND and contractors. Long development cycles (as much as ten years) and rotation of personnel implied a need to enable users new to the project to inform themselves about reasons for earlier requirement compliance decisions made by others, as well as a training requirement for those unfamiliar with HF guidelines and issues. Personnel issues such as projected crew size and roles were seen as important design drivers but were dealt with only in very broad terms in the early design stages. The importance of task insights and contractual checklists for HF requirements created at an early stage of design were seen as the basis for later compliance reviews. The diminishing supply of design staff with knowledge of ship operations and rapid changes in technology that decrease the relevance of operational experience for the subsequent generation of ship design made access to task based data during design reviews important.

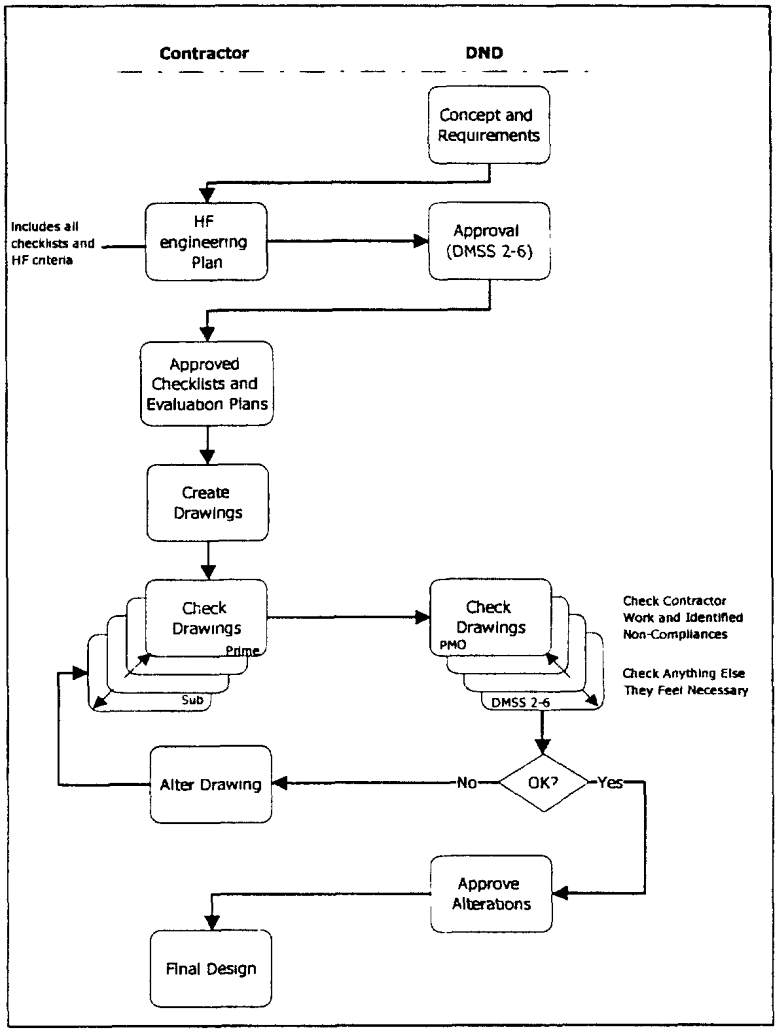

Fig. 1 The relationship between DND and contractors during the design cycle

In summary, there was a need for support to generate, communicate and maintain HF related requirements, criteria and decisions among diverse groups of personnel from different organizations with joint responsibility for design decisions, sometimes over a period exceeding ten years (2). More specific requirements by design stage included:

- **Pre-design:**
  - Guidance on the significance of HF issues for the feasibility of different operational options.
  - Characterization of operational requirements to permit ready evaluation at later reviews.
- **Concept exploration:**
  - A simple 2D or 3D drafting tool to conduct "what if" assessments of basic space layouts.
  - Access to text based guidelines to prompt consideration of key HF issues.
  - Access to user reports on lessons learned from relevant predecessor systems.
- **Preliminary and contract design:**
  - Access to intelligent / tutorial guidelines for resolving HF issues.

- Access to text based standards or guidelines for space design.
- Access to 3D or 2D drafting tools using anthropometric data.

- **Detailed design:**

- Tools to permit HF specialists within DND to quickly review compliance of contractor's drawings with previously established requirements and to audit the decision trails.

Given these requirements, appropriate computer based tools that might support HF in the naval design process fell into four categories (3):

1. **Cognitive tools** to aid problem solving and decision-making including procedures to follow and logical algorithms to manipulate data.
2. **Databases** and the means to access them readily, such as compendiums of HF data, audit trails during the design cycle, and user reports from predecessor systems.
3. **Modelling tools** to simulate design outcomes based on data from one or more of the databases.
4. **Records** of design decisions and the reasons for them for future reviews or compliance checks.

From the requirements and this list of tools the functions of a computer-based system for supporting human factors engineering in the ship design and review process (Human Factors Engineering Intelligent Computer-Aided Drafting and Design - HFE-ICADD) were established in the following areas:

- **Integrate contractors into the design process:**

- Act as a central record of HF design criteria and the F plan.
- Provide a facility to link DND and Contractor technical working groups
- Capture operational experience in the form of task analysis data.
- Track multiple iterations of a drawing or debate over an HF issue.
- Provide hardware/software flexibility to support a range of contractor and DND sites.

- **Provide for the generation and use of HF requirement checklists to enable:**

- Review and tracking of design compliance related decisions.
- Cutting and pasting from software based HF guidelines.

- **Permit rapid, and eventually automatic, dimension checking for:**

- Changes.
- Head room, reach and viewing distances, passage dimensions, space entry.

- **Facilitate incorporation of task data involved in use of shipboard spaces by:**

- Communicating task data and design criteria among DND and contractor groups.
- Relating design criteria decisions to tasks performed in the space under review.
- Permit entry of data on compartment use for personnel, tasks, reach, vision.

- **Fit with existing or emerging software products supporting HF in the design cycle.**

- **Provide for key tasks such as:**

- Preparing drawings for review, choosing and checking items on a drawing in terms of compliance with a requirements checklist and task requirements, record decisions and reasons, build and edit checklists.

3 OVERALL ARCHITECTURE OF HFE ICADD

The HFE-ICADD system was designed as an end-to-end hardware-software solution integrating custom software with Commercial Off-The-Shelf (COTS) packages and existing software systems at the DND (4). The various software packages are incorporated into five modules in the HFE-ICADD architecture.

- The ***'Checklist'*** module comprises a collection of tools to import text from existing documentation, define, assemble and structure requirements checklists for a given project.
- A ***'Tasks'*** module contains a reference material and data on the tasks that will need to be performed in the space under review.
- A ***'Drawing Module'*** includes scanning and vectorization tools that save data in a Graphical files Manager on a CD-ROM Juke-box device. Various 2D-3D, image-processing and red-lining tools allow visualization and editing of graphical files.
- A ***'Mannequin'*** module, integrates the high-end mannequin package *'Safework'* to help reviewers visualize and check clearance, reach, and other task-related features for the appropriate range of body shape, size and posture issues.
- The ***'Case-based'*** module comprises custom software to carry out Automatic Constraint checking, provides a Previous Case manager, and a Design Review Task planner (or intelligent help system).

An overall '***Project Manager***' function allows the user to access each of the modules in the system while providing the logic and file conversions necessary to allow a series of COTS and custom developed products to work together. Fig. 2 illustrates how the modules inter-operate in the comprehensive HFE-IACDD system.

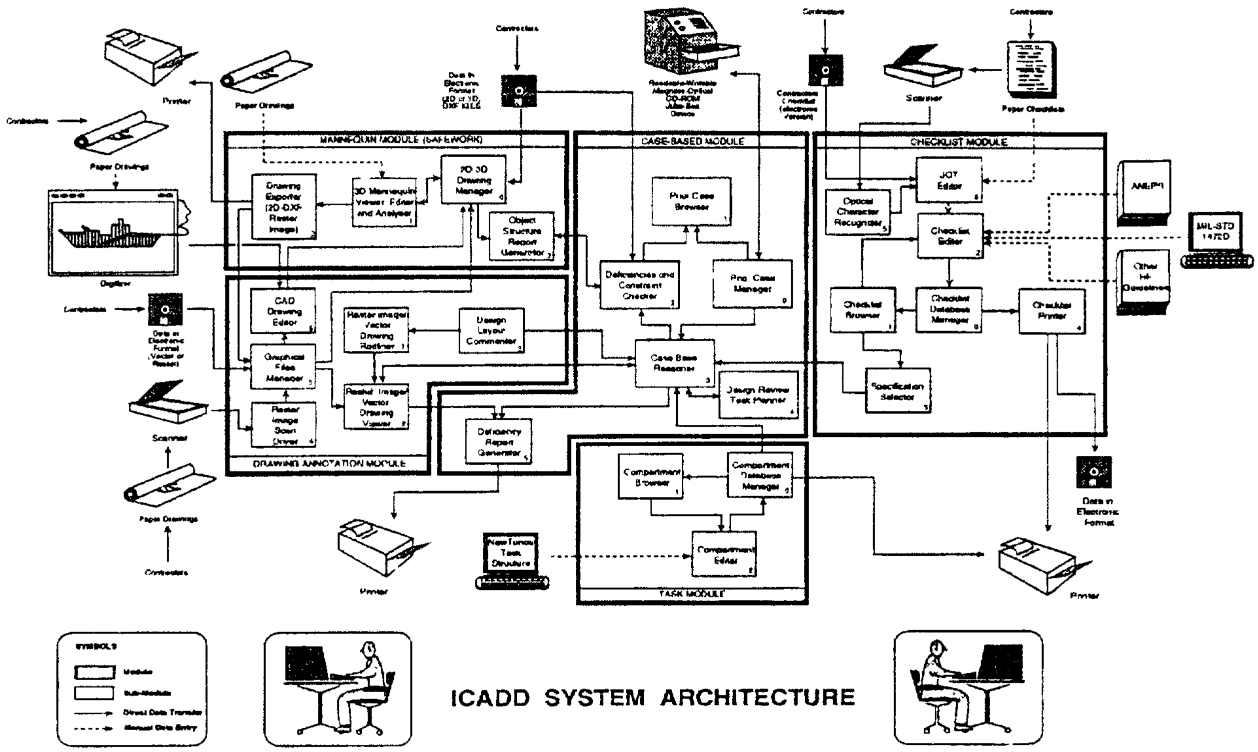

Fig. 2 HFE-ICADD Architecture

4 HFE-ICADD MODULES

4.1 THE CHECKLIST MODULE

In the ship design process, DND specialists must evaluate the compliance of proposed designs with HF guidelines. To facilitate this process they need to extract relevant HF guidelines and compile them into concise checklists (Fig. 3).

The ***Checklist Module*** allows the user to create a checklist of design criteria that a space layout is required to meet. Terms within the checklists provide indexing and search keys for locating previous versions of the same compartment or other compartments where similar design issues have been reviewed. New checklists can be created by cutting and pasting from existing checklists and guidelines, or by manually entering new checklist items into the checklist structure. The results of a checklist-based review of a compartment form the core of a deficiency report generated by the *Case Based Module* (see below).

4.2 THE TASK MODULE

Many HF design criteria are user and task dependent. The ***Task Module*** allows the user to enter information about the tasks that must be completed in a workspace (Fig. 4) As many layout criteria are often related to accomodating the operators' tasks, it is beneficial for the HFE-ICADD user to have quick access to information about who works in the space, where they have to travel, what they must reach, what they must see, and with whom they communicate. Because these data can be transferred between reviewers, the module should allow the knowledge of operator tasks to grow as different users interact with a compartment under design As a ship is designed or built, the Task Module also allows the user to attach photographs or video clips to the task information to allow the layout reviewer to better visualize the space and the associated user tasks.

4.3 THE DRAWING ANNOTATION MODULE

The ***Drawing Module*** allows the user to bring ship layout drawings into the HFE ICADD system. This module accommodates the full range of drawing formats including paper, which are scanned in, and electronic CADD files which are imported and manipulated with the included CADD software (currently MICROSTATION). This module provides users with the ability to load into the computer and to display on the screen 2D-CAD drawings or scanned raster images using their preferred CAD tool (of two COTS packages). The *Drawing Module* provides a Redliner software package that allows the user, once a file is in electronic format, to mark up the drawing during the review, making notes and illustrations on top of the drawing itself. The annotated images and text can be transferred into a deficiency report.

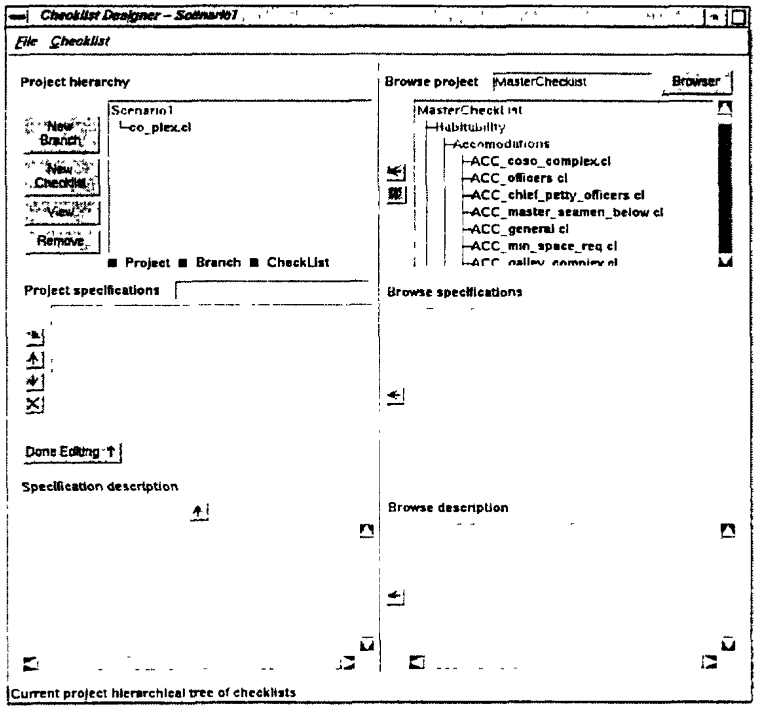

Fig. 3 Screen from the Checklist Builder

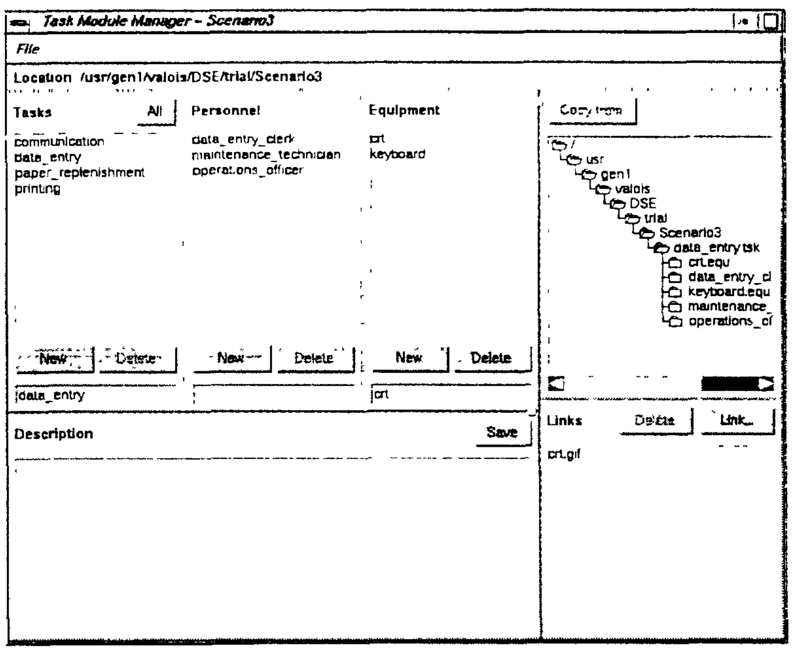

Fig. 4 The Task Module

4.4 THE MANNEQUIN MODULE

Many HF problems in ship compartment design are related to the range of sizes of the potential users. Using the *Mannequin Module*, 3D mannequins of appropriate sizes can be generated and integrated into the layouts to enable the reviewer to conduct HF studies. The module allows the user to import 3D renderings of a ship space or to quickly create their own drawing of key features of a space. Representative human form mannequins generated using Safework (5) are then inserted into the 3D environment where lines of sight, reach, force requirements, travel clearances and other variables can be evaluated. These 3D visualizations with mannequins are also available to illustrate design concerns and can be transferred to a deficiency report.

4.5 THE CASE-BASED MODULE

This custom-developed module contains the 'intelligent' features of HFE-ICADD:

(a) The Previous Case Manager.

(b) The Automatic Constraint Checker.

(c) The Intelligent Help System.

4.5(a) Previous Case Manager

DND naval procurement programs typically extend over a decade. During this period, there is constant staff turn-over making the tracking of previous decisions difficult. The project teams repeatedly have to get up to speed on and rebuild this project knowledge. This module is designed to assist in this challenge by relating a current case to prior cases that may have similarities, or to previous iterations of the same case. This module is based on conceptual neighbourhoods technology that operates on a structured domain thesaurus (6). A weighting algorithm keeps track of how close the conceptual neighbourhoods are of a base case concept.

The similarity between cases can relate to various viewpoints such as a case's problem, context, solution and design review process (Fig. 5). The module performs an intelligent search by identifying concepts that are related to those characterizing the current case by navigating through a structured thesaurus.

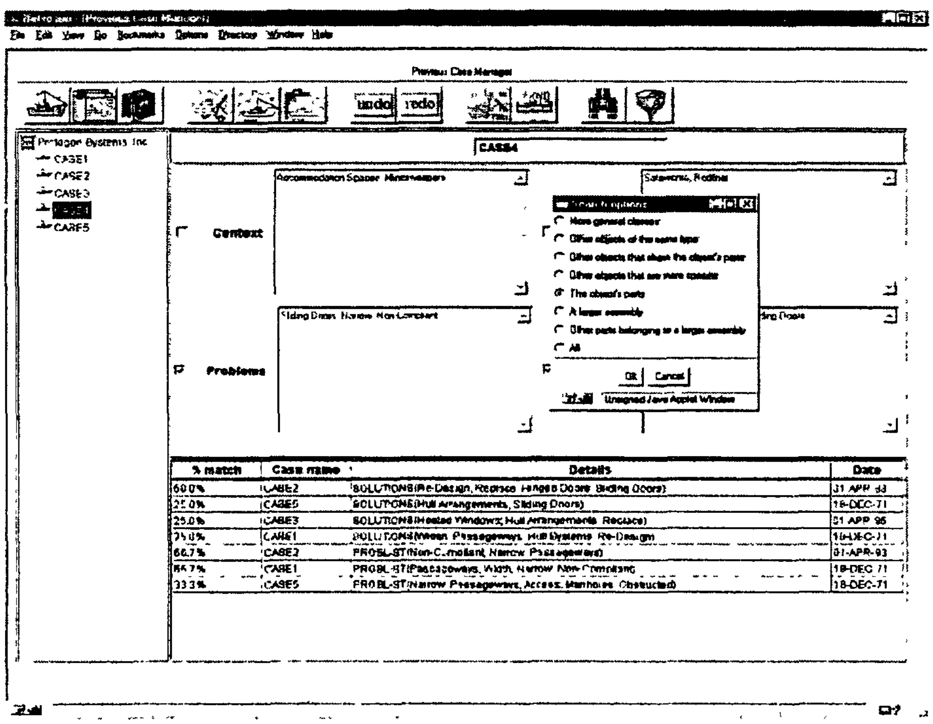

Fig. 5 The Previous Case Manager

(This Figure shows how aspects of a case can be described with different input windows, and the results ranked and displayed. Double clicking on a result item displays the item's project information.)

A tool has been developed to view the domain thesaurus on which this module is based. Displaying a network on screen is typically difficult and confusing with nodes and links overlapping.

The approach that has been taken for this project is to develop a dynamic system that adapts to the focus of interest at any given time. It displays the thesaurus as a collection of terms with rubber-band links. The display is dynamic since the user may pull on any term to bring it in better view; the terms related to it will follow suit with various forces being applied on the rubber-band links (see Fig. 6).

Both the Previous Case Manager and the Thesaurus Browser Tool have been implemented with Thin-client Java modules interfacing with a server system written in Lisp.

4.5(b) Automatic Constraint Checker

An important and labour-intensive aspect of the DND HF end-users activities deals with the review of compartment design layouts. The goal is to check for compliance with a set of design requirements and guidelines, and flag areas that may be in violation. In the operational prototype implementation of HFE-ICADD, this module was designed as a tool for the use of DND staff (7). However, a thin-Java client technology was selected allowing the user to interact with the server layout analysis system via a web site. This allows the system to be expanded later into a web system where naval engineering contractors could validate their designs themselves on DND's web site. This would allow DND staff to focus their efforts on the development and management of design requirements and guidelines, and reduce their involvement in design review activities.

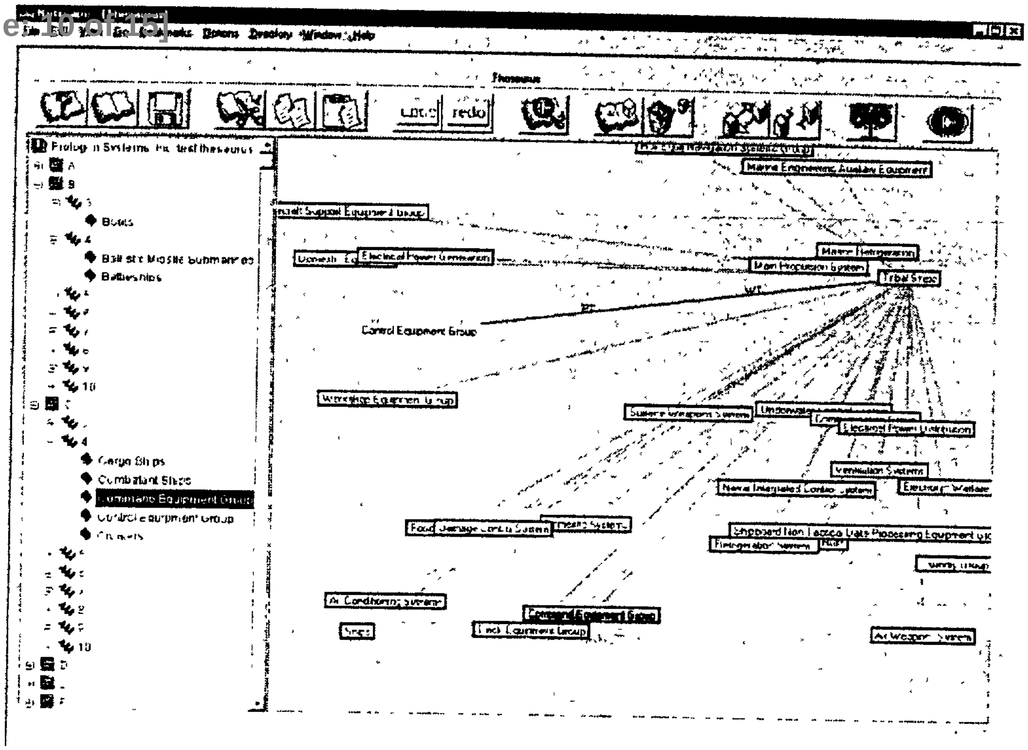

Fig. 6 Sample Display of a Conceptual Neighbourhood in the Thesaurus

(This Figure shows how users can reconfigure the display by selecting and dragging a term to a more suitable area on screen. 'Rubber-band' links reconfigure related terms automatically.)

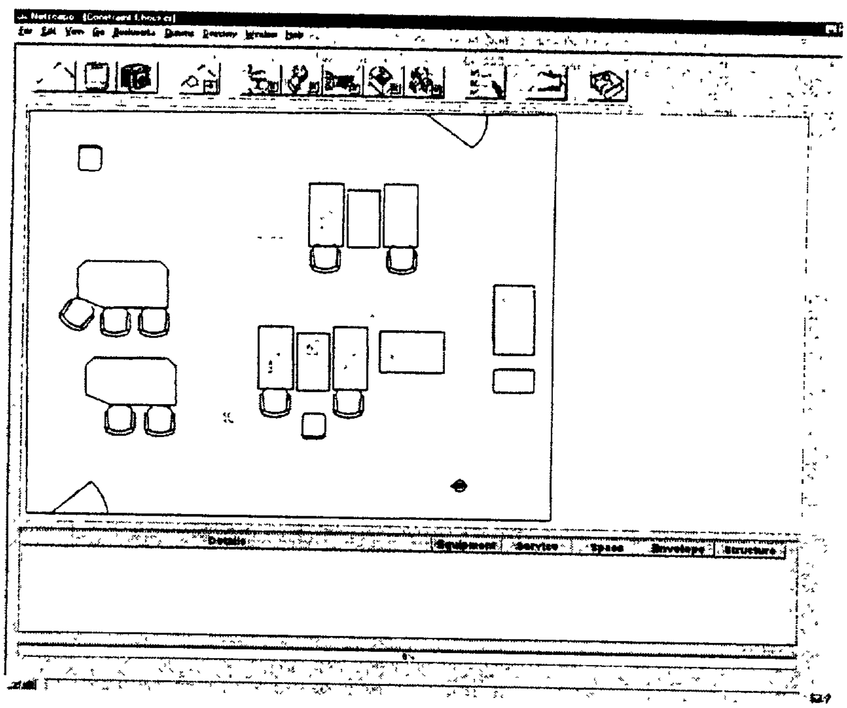

Fig. 7 Sample Compartment Layout Design Input File

The input to this module is a 2D plan layout of the compartment (see Fig. 7 above) on which the system performs object recognition and scene interpretation analyses.

When design problems are identified, they are highlighted with mouse-sensitive red squares (see Fig. 8) on which the user may click to bring up textual descriptions of the problems (see Fig. 9).

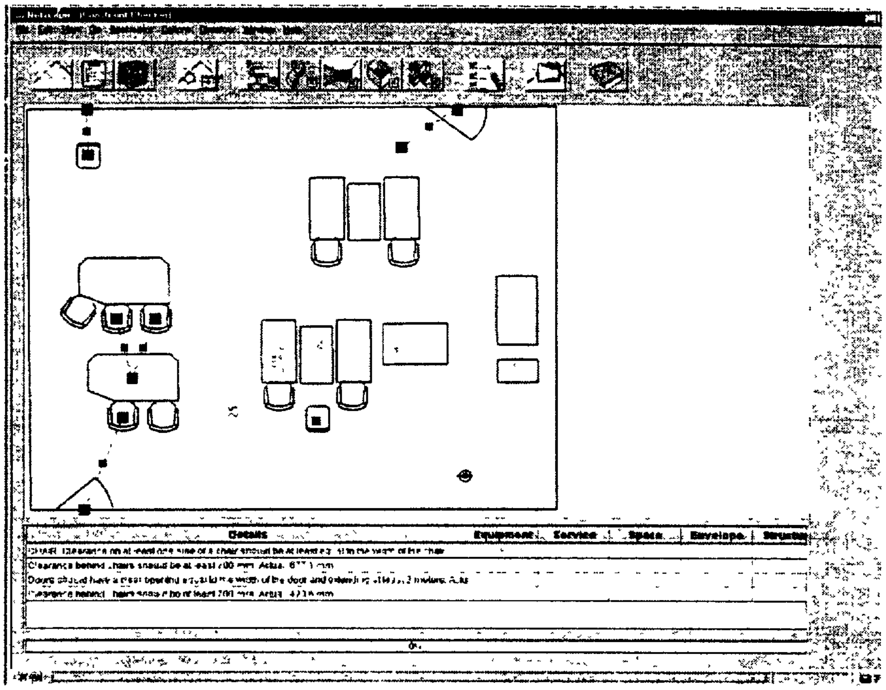

Fig. 8 Sample Compartment Layout

(Problems are flagged with red squares (■) by the automatic constraint checking process.)

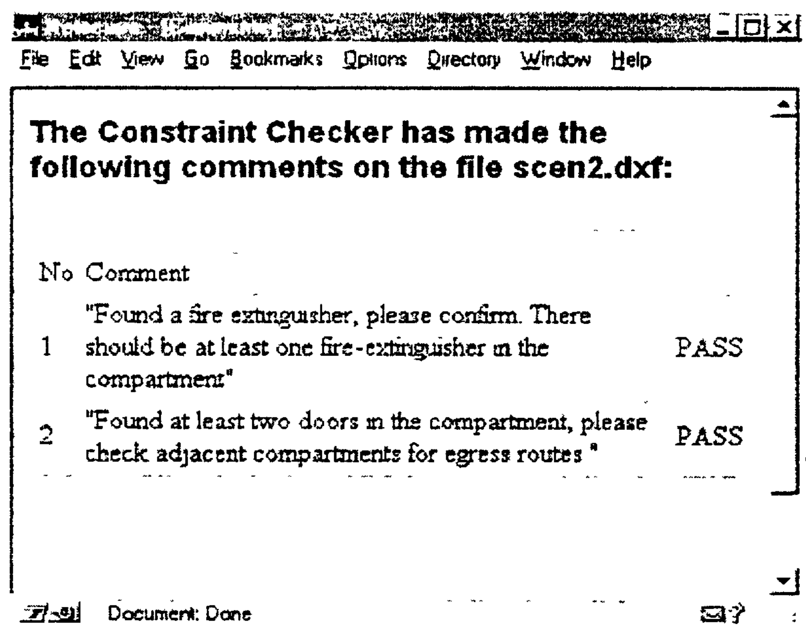

Fig. 9 An Automatically Generated Report

(Generated by clicking on a mouse-sensitive red square shown in Fig. 8*)*

This module has been developed as a Thin-client Java interface interfacing with a server application written in Lisp.

4.5(c) Intelligent Help System

HFE-ICADD has been designed to assist the user operating in a complex procurement and design process involving multiple teams. This module has been designed to provide intelligent on-line help to the users on the tools and processes involved in their work. It has been designed as a context-, user-level and dialog-history sensitive system. In other words, the system entertains a dialog with the user with knowledge of their level of experience and of information that was provided in previous interactions throughout the dialog. For example, if the user were to ask the same question twice, the system would assume that the user does not grasp some of the fundamental concepts and will expand in these areas. Furthermore, the system integrates hypertext capabilities that allow the user to expand on key-words used in the dialog texts

The module applies user models, dialog histories and dynamic information on the tasks being carried out to provide intelligent advice. A wide variety of question-types are provided, such as:

- What is xxx? Tell me about yyy. Check the validity of zzz. Should I do aaa.? Should I aaa... or bbb?
- How do I decide on nnn? How do I decide if mmm? How do I decide if rrr or qqq?
- At what point should I do sss? How do I do kkk?

The *Intelligent Help Module* has been developed completely in Java (see Fig. 10), based on the MADIS technology and its prototype Prolog implementation, is part of a licensing agreement with the Canadian National Research Council Canada's Institute for Information Technology.

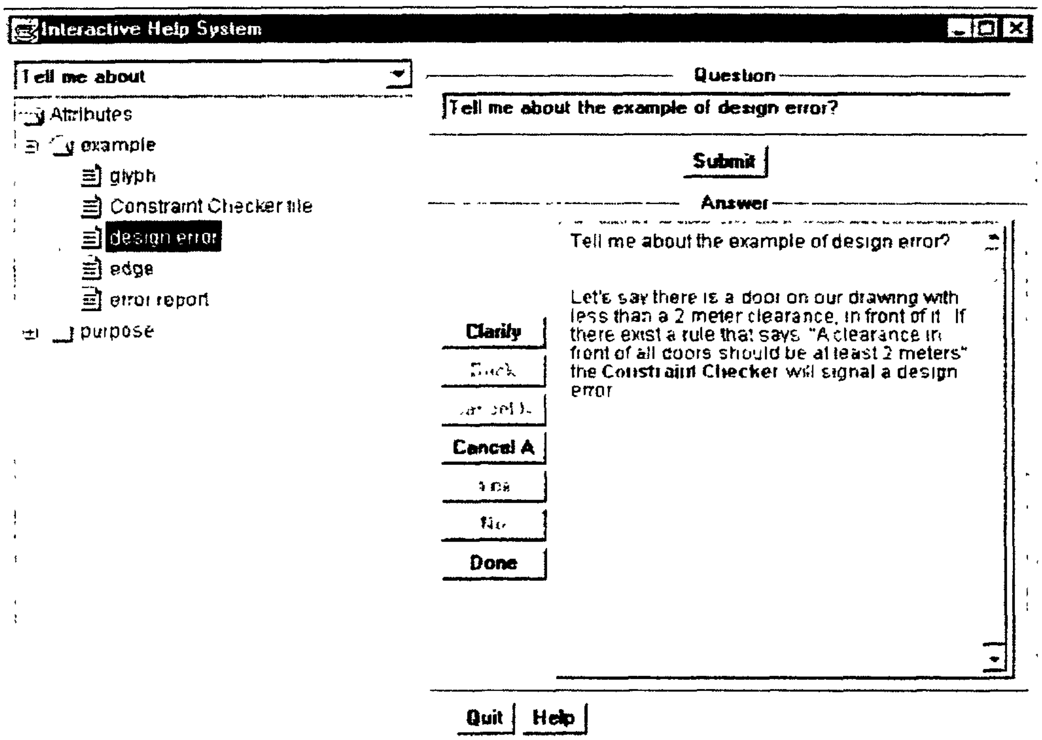

Fig. 10 Display of Sample Step in a Help Dialogue Interaction

5 USER TRIALS

During the development process, independent user trials and Human-Computer Interface (HCI) reviews were conducted and the results fed back to the software developers. For example the second user trial lasted for two days and employed six participants with a cross section of experience in naval architecture, HF, and DND naval design projects. These participants were first trained for two hours in the functions of the prototype HFE-ICADD, including a demonstration. Then, trial participants worked through five scripted and one free form scenario designed to cover all areas of HFE-ICADD functionality and key tasks.

Scenarios included reviewing a drawing of a ship's compartment for HF deficiencies using an existing checklist; reviewing a mannequin model using a task list and the red-lining function to create a deficiency report; building a checklist; and others. During or after the scenarios, observers noted any apparent areas of difficulty, delay or frustration; participants rated selected functions on standard rating scales; and comments were solicited during user group reviews after each scenario.

Participants provided several different types of rating for the software:

- *Ease of use* and *Usefulness* of the software for each task in each scenario.
- Overall usability of each software feature after all scenarios were completed.
- Ratings for HCI features such as screen layout and cursor control
- A rating for the familiarization and training package.

Both trials resulted in generally favourable ratings for overall ease of use and utility for the software while revealing a number of specific concerns (8). Most of these concerns could be traced to a lack of functional integration between the different software modules and related file sharing problems which users found frustrating and time consuming to overcome. Other examples included the need for more effective error trapping and correction, more short cut keys for experienced users, and indication to users that the software was actually active during apparent pauses. The results of the user trials will be used to improve the prototype and its associated training package when the software is converted to a web-based package for use on a PC platform.

6 HOW OTHERS COULD USE THE HFE-ICADD CAPABILITIES

HFE-ICADD was developed over a four-year period dictated by available funding. During that period several changes occurred in DND that have limited the use made of the tool. At about the time that it was commissioned, reviews of DND life-cycle management functions resulted in reductions in the number of personnel available to use HFE-ICADD in-house

Also, to date the way of working has not changed significantly. While the developers and intended users of HFE-ICADD had anticipated that the design review process would switch to CAD, most life-cycle support activities associated with human factors issues have retained the use of paper drawings. The effort available to deal with human factors issues has focussed on dealing with immediate problems using tried and tested procedures, rather than being diverted to deal with the implementation of the new technology. Limited use of HFE-ICADD has the unfortunate consequence of limiting the development of a sufficient body of examples for the case-based reasoning functions to have high utility.

Other developments now require changes to HFE-ICADD to improve its utilization. First, departmental policy has evolved to emphasize a more business-oriented relationship with contractors. System acquisition and life-cycle support is to be based, whenever possible, on the acceptance by industry of the responsibility for design and development of requirements established and monitored by DND. This change resulted in HFE-ICADD being developed, not as a design tool as originally conceived, but as a design review tool. Current thinking among the potential users is that the move to a 'business oriented relationship' with industry will require a computer network between clients and contractors as part of the process and the normal way by which business is conducted Thus, for maximum benefit to be obtained from HFE-ICADD, industry users must be able to access it and it must be compatible with their computer systems.

Also, since the development of HFE-ICADD was initiated, a standard 'cubicle' office space has been adopted by all DND life-cycle management directorates, which precludes the effective use of the scanners and plotters. The Information Technology (IT) environment in DND has been standardised on personal computers running COTS software. The current configuration of HFE-ICADD does not meet that requirement and it does not receive in-house support. Finally, under a business change initiative in DND, templates have been developed for the preparation of Statements of Requirements that require human factors issues to be addressed, including operator roles and functions; the operator-machine interface; health hazards and system safety. This business change initiative is associated with the adoption by project management offices of software tools for the development and tracking of requirements. Thus there is a potential link between the activities of those involved in requirements development and design review, and HFE-ICADD should be compatible with the use of requirements management software.

In response to these developments, DCIEM recently contracted two studies to implement HFE-ICADD within the current DND IT environment and to exploit the changes in SOR templates and the use of requirements management software

The first study was conducted by a company with experience in the use of requirements management software and with some experience of HFE-ICADD. The contractor reviewed the functions provided by HFE-ICADD and the potential for current COTS software to provide that functionality on a PC platform. The review of COTS products included the standard DND office automation suite of Windows 95/98, Microsoft Internet Explorer 4, MS Office 97, MS Project 98, MS Outlook and a few other applications such as Adobe Acrobat and a requirements management soft-ware package. The study developed a proposed configuration for HFE-ICADD running on a PC platform. The feasibility of the proposed configuration was evaluated by analyses of user tasks originally used in the HFE-ICADD training package.

The second study was performed by one of the developers of HFE-ICADD (Protogon Systems Inc.) The aim was to review, experiment, and validate the approach, architecture and recommendations for implementation in a COTS software/PC platform working environment. Specific aspects of the proposed architecture were implemented on a trial basis. In addition the opportunity was taken to address findings from the user acceptance trials of the original HFE-ICADD software and to propose improvements. The study concluded that the majority of the current HFE-ICADD functionality can now be replicated using COTS software. However, the unique aspects of HFE-ICADD, specifically the case-based reasoning and the constraint checker, cannot be replicated using currently available COTS software.

The proposed COTS implementation uses the architecture originally developed for HFE-ICADD with the various functions being undertaken by off-the-shelf office, CAD and requirements management packages. In this respect there are parallels between the proposed solution and some of the capabilities developed by the USN for the DD-21 project. This is not surprising, since the process of design and design review typically requires the user to identify sources, retrieve information, evaluate its implications, encode it, store it etc.

One particular benefit is that the study confirmed how COTS Requirements Management software could be used to implement the checklist functions of HFE-ICADD. This should allow users to link their design review activities more closely to the requirements development and tracking process within DND. The implementation of such an approach should also facilitate close links between those interpreting the requirements and developing designs, and those human factors specialists evaluating the proposed designs on the part of the end-users.

Given the COTS configuration of the basic features of HFE-ICADD, other potential users could implement similar systems. However, it is hoped that the COTS approach will facilitate the implementation and use of the basic features of HFE-ICADD in such a way that sufficient case histories can be collected for implementation in the case-based reasoning functions, which remain one of the unique features of the system.

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