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GRAPHIC USER INTERFACE DESIGN FOR MAPPING, INFORMATION, DISPLAY, AND ANALYSIS SYSTEMS

by

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June 2000

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This thesis evaluates both the interface design process and the map-based mission planning tools of the Loosely Coupled Components Research Group, Naval Postgraduate School for human factors usability. After identifying flaws in the process and usability problems in the interface designs, a new software design process and map-based mission-planning tool are developed. A usability study was conducted on the new mission-planning tool, determining it to be a usable product while establishing baseline data for future interface improvements. The map-based mission-planning tool, written in the Java programming language, is called the Mapping, Information, Display, and Analysis System (MIDAS). In its Beta form, MIDAS can display any geo-referenced map or image and allow users to annotate it with several graphical tools. Future versions will incorporate existing map-based decision-aiding tools such as optimal track routing, intelligence image rubber-sheeting, and wirelessly networked unit tracking. This thesis recommends the incorporation of human factors early in the software design process and quality usability studies on interfaces to ensure a usable product.

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GRAPHIC USER INTERFACE DESIGN FOR MAPPING, INFORMATION, DISPLAY AND ANALYSIS SYSTEMS

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ABSTRACT

This thesis evaluates both the interface design process and the map-based mission planning tools of the Loosely Coupled Components Research Group, Naval Postgraduate School for human factors usability. After identifying flaws in the process and usability problems in the interface designs, a new software design process and map-based mission-planning tool are developed. A usability study was conducted on the new mission-planning tool, determining it to be a usable product while establishing baseline data for future interface improvements. The map-based mission-planning tool, written in the Java programming language, is called the Mapping, Information, Display, and Analysis System (MIDAS). In its Beta form, MIDAS can display any geo-referenced map or image and allow users to annotate it with several graphical tools. Future versions will incorporate existing map-based decision-aiding tools such as optimal track routing, intelligence image rubber-sheeting, and wirelessly networked unit tracking. This thesis recommends the incorporation of human factors early in the software design process and quality usability studies on interfaces to ensure a usable product.

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DISCLAIMER

The reader is cautioned that computer programs developed in this research may not have been exercised for all cases of interest. While every effort has been made, within the time available, to ensure that the programs are free of computational and logic errors, they cannot be considered validated. Any application of these programs without additional verification is at the risk of the user.

All icons images used in software for this thesis were either designed by the author or acquired as public imagery provided by Sun Microsystems™. Due to common industry-wide iconography, included images may bear resemblance to existing commercial graphics. No attempt has been made at infringing on any copyrighted imagery.

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LIST OF SYMBOLS, ACRONYMS AND/OR ABBREVIATIONS

CEC	Cooperative Engagement Capability
COTS	Commercial Off the Shelf
CPOF	Command Post of the Future
DARPA	Defense Advanced Research Projects Agency
DISA	Defense Information Systems Agency
DoD	Department of Defense
GIF	Graphic Interchange File
GPS	Global Positioning System
GUI	Graphic User Interface
GRI	Geo-Referenced Image
HCI	Human Computer Interaction (Interface)
HF	Human Factors
LAN	Local Area Network
LCC	Loosely Coupled Components
LW	Land Warrior
LW2K	Land Warrior 2000
MHz	Mega Hertz
MIDAS	Mapping, Information, Display and Analysis System
MS	Microsoft®
NIMA	National Imagery and Mapping Agency
OR	Operations Research
PDA	Personal Data Assistant
RAM	Random Access Memory
RPV	Remotely Piloted Vehicle
SEAL	Sea, Air & Land
SIPE	Soldier Integrated Protective Ensemble
SOFLCC	Special Operation Forces / Loosely Coupled Components
USA	United States Army
USMC	United States Marine Corps
USN	United States Navy
USSOCOM	United States Special Operations Command
VDT	Visual Display Terminal

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EXECUTIVE SUMMARY

Joint Vision 2010 establishes a conceptual template for leveraging technological opportunities to achieve new levels of effectiveness in joint warfighting capabilities for the United States military. Of JV2010's five areas of focus, Information Superiority is the most affected by emerging computer, communication, micro-miniaturization, and Internet technologies. Information Superiority will play a dominant role in the future of warfare. Technological advances in satellite imagery, remotely piloted vehicles, mobile communications, the Internet, and GPS alone have already swamped military leaders with more information than they can effectively use in a tactical situation. The ability to collect, analyze, and disseminate vast quantities of useful information is Joint Vision 2010's primary vehicle to achieve "Battlespace Dominance."

The Department of Defense has responded to Joint Vision 2010's technological challenge with various advanced warfighting programs like the Command Post of the Future project, the Land Warrior 2000 project, and the Naval Postgraduate School Loosely Coupled Components Research Group. All three programs employ *Internet-time* technologies in wireless networking, command and control, and mission planning.

How do military leaders know they are getting the biggest technological bang for their research dollar? How do they know if the newest techno-information system is overwhelming their commanders or giving them the Information Superiority they need to win the battle? The answer to these questions is based in Human Factors and the Human Computer Interface. Whether it is a laptop computer screen, a remote imaging device, or a computer aided rifle-sight, humans are interacting with a computer. No matter how powerful the interface appears, the sailor or soldier operating it must be considered in its

design. Technological advances are only moving in one direction – smaller, faster, and more complicated. Knowing that military research and development has fully incorporated the user's needs into interface design ensures a useful, powerful, and effective information system.

This thesis evaluates the human computer interface of existing map-based mission planning tools developed by a faculty and student research group in the Naval Postgraduate School's Operations Research Department. After careful human factors based analysis, various usability flaws were identified and an improved Graphic User Interface was designed. The new interface, written in Java, utilizes any imagery that can be geo-referenced and will soon incorporate numerous operations analysis decision tools for the military planner. A usability study was conducted and results were compared with industry and the DoD standards for usable interfaces. The new map-based planning tool's interface was determined to be usable and therefore was accepted as the base interface for further operations analysis decision-making tools. Not only is the new graphic user interface a DoD model for Java map-based mission planning software, but the Loosely Coupled Components research group is leading the way in military software development that incorporates human factors in the software design process.

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I. INTRODUCTION

The module is a scale of proportions that makes the bad difficult and the good easy.

- Albert Einstein to Le Corbusier (1964)
referring to intellectual model representation

A. PROBLEM

Joint Vision 2010 establishes a conceptual template for leveraging technological opportunities to achieve new levels of effectiveness in joint warfighting for the United States military (CJCS, 1996). Of JV2010's five areas of focus, Information Superiority is most affected by emerging computer, communication, micro-miniaturization, and internet technologies.

The Information Superiority concept exploits advances in collection, processing, and dissemination technologies to "mitigate the impact of the friction and fog of war," while at the same time, denying the enemy the right to the same (CJCS, 1996). Information Superiority is achieved by fusing and processing information from all available intelligence sources and disseminating a usable product to thousands of locations in a timely manner. Using superior information, our joint fighting forces will achieve "Dominant Battlespace Awareness" allowing increased force dispersion, mobility, and lethality (CJCS, 1996).

The Department of Defense has responded to Joint Vision 2010's Information Superiority call with several technology based research programs. Some examples are

DARPA's Command Post of the Future (CPOF), the Army's Land Warrior 2000 program (LW2K), and the Naval Postgraduate School's Loosely Coupled Components (LCC) research group.

The LCC research combines several Operations Research based tools to aid in map based mission planning. Some of the tools are: National Imagery and Mapping Agency (NIMA) formatted map display, intelligence imagery rubber-sheeting, route-planning, shortest-path decision aids, whiteboard-style map annotations, battlefield training monitors, and field-deployed database servlets. Though each is an effective stand-alone tool, when fused into one interface they become ineffective and unusable beyond the academic environment. The fault in the software's poor usability lies in its outdated software design process. In order to make the software more usable, the software design process must be improved and adapted to industry-wide Human Computer Interface (HCI) design standards. After examining the existing software under the new design process, it was determined by the LCC research group that the only acceptable approach was to design a new map-based mission-planning tool from the ground up. This thesis proposes a replacement to the existing LCC map-based mission-planning tool and developed a human factors software design methodology for future LCC Operations Research systems.

B. HUMAN FACTORS AND GUI DESIGN

Information Superiority based in technological advances is achieved when a human is able to successfully use a computer to collect, process, and disseminate information. Each DoD research group is developing its own graphic user interface

(GUI) to manage these processes. Their GUI's will allow soldiers, sailors, airmen, marines, medics, commanders, or SEAL's to interact with their computers to exchange information with any computer. Though technology and software electronically bridge gaps between dissimilar computer systems, process large quantities of information, and adapt to unknown hardware, the soldier is the part of the equation that puts the technology to use. If she or he is bogged down wrestling with menu structure or is unfamiliar with applications of his software, no technology can lead to success. A strong set of Human Computer Interface (HCI) guidelines is needed to ensure the soldier's information display system has been designed with his tasks and needs in mind.

1. Graphic User Interfaces

The success of Microsoft Windows® and the Macintosh® O/S as popular Graphic User Interfaces is based on their designers' strong incorporation of the Mental Models and Metaphors methods as discussed by Wickens, Gordon, and Liu (1998). The Mental Models method is a dynamic model of the user's knowledge of the following: system components, how the system works, how components are related, what the internal processes are, and how the user affects the components. The Metaphor method is the process of using objects and events in a software system that are taken from a non-computer domain such as "desktops," "cut and paste," and "trash cans" (Wozny, 1989).

Mayhew (1992) states that designers should enable the user to develop an effective Mental Model. An effective mental model is one in which the user can mentally represent the relationships between or perform actions on working components of the

GUI. Wickens, Gordon & Liu (1998) provide four suggestions to improve the mental model, (1) Make invisible parts and computing visible to the user (i.e. dragging a file to a trash can to delete it), (2) Provide feedback to the user (i.e., showing statuses of loading, saving, printing), (3) Build in consistency (i.e., established patterns and rules common across applications), and (4) Present functionality through a familiar metaphor utilizing real world analogies (i.e., physically moving a mouse pointer through the non-physical environment of a computer display).

The Metaphor Method, the second half of effective GUI design, provides the user with familiar metaphors for completing tasks. One example is the ability of World Wide Web users to chat on the Internet in a "room." Though none of the actions physically occur, users can identify with the metaphor of entering a room full of people and chatting with one or all of them. Other less obvious metaphors include matrix-structured spreadsheets, desktops, clocks, calendars, and back/forward icons for turning "pages" of virtual books, manuals, or Web pages.

Interface designers must also be careful using metaphors that are also vulnerable to errors. Differences between the metaphorical world and the software system, if not made explicit, can cause errors or gaps in the user's mental models of the software system (Halasz & Moran, 1982). Examples of metaphor error are turning pages left and right in a virtual book by using Page Up / Page Down keys or pressing the MS® "Start" button to initiate a computer shutdown.

GUI technology and design are not limited to conventional keyboards, monitors, and speakers. GUI design, based strongly on Mental Models and Metaphors, is crucial to implementing successful present and future software applications. "Thirty-seven to fifty percent of [industry] efforts throughout the software life cycle are related to the system's user interface" (Hefley, Buie, Lynch, Muller, Hoecker, Carter, and Roth, 1994, p.315). Financial implications of these efforts force software development companies to join human factors engineers and software programmers at the onset of system design. Their goal is to reduce the short and long-term costs associated with poor design. As computers and displays become smaller, GUI's will become ever more important and will be relied upon to maintain the information bandwidth required to complete complicated tasks. Task completion, however, is not the only yardstick for declaring a GUI design successful. The experiments in *usability* measure the quality and effectiveness of GUI designs.

2. Usability

The key to a successful GUI is whether or not it is designed with human usability as its primary goal. In the past decade, computer use has expanded to toddlers and the elderly and from making scientific calculations to writing e-mail and joining virtual combat missions. Software companies can no longer afford to push highly technical and unfriendly software on customers. To stay in business, they are meeting these widening demands through extensive usability research and adherence to HCI guidelines. According to Nielsen (1993), software usability is traditionally associated with *learnability* (ability to quickly become productive with software), *efficiency* (high productivity after initial learning period), *memorability* (relearning is not necessary after periods of non-use), *errors* (low error rate, ease of error recovery, no catastrophic errors), and *satisfaction* (subjectively determined).

There are many ways to measure whether a Graphic User Interface meets the minimum requirements in an established set of standards. Each interface requires a different testing method. The most commonly used methods to measure usability are number of errors, time to perform tasks, and user subjective reactions.

3. Usability Testing

The overall goal of interface usability testing is to identify and rectify usability deficiencies in computer-based human computer interaction (Rubin, 1994). There are many measures of a GUI's usability. Listed here are a few used by Microsoft's® usability labs: benchmark studies, heuristic reviews, task analyses, error analyses, and competitive studies (Microsoft, 1998). Nielsen (1999) explains the simplest usability metric is success rate, which is the best estimate of the true success rate for a similar population user. In order to determine if a success rate is acceptable, standards must be established prior to usability testing. Either benchmarks from previous studies or heuristic industry standards provide the ruler for newly collected data (Nielsen and Molich, 1990, Nielsen 1994). Industry standards for icon identification success rates average 70% for initial exposure and 100% there after (Bickford, personal communication, 11 May 2000). Standards for acceptable task analysis success rates are 90% (Bickford, personal communication, 11 May 2000).

4. Human Computer Interaction Guidelines

In order to make HCI successful across all platforms and software, interface guidelines must be thoroughly integrated into the product realization process (Lund & Tschirgi, 1991). But before HCI and the production processes can be integrated, HCI must be well understood.

Dix, Finlay, Abowd & Beale (1998) define HCI by breaking it into three parts. The *human* user is any individual or group of users in an organization participating in task or process completion. The *computer* is any technology such as a palmtop, laptop, desktop, mainframe, or process control system. *Interaction* is any direct or indirect communication between a user and a computer to accomplish tasks. Since the early advent of Macintosh's® desktop, Microsoft's® Windows series, and the vast array of Internet browsers, human factors experts have been applying their expertise to HCI.

It is also important to understand that common philosophical HCI guidelines serve as a guide and base to all interface designers, no matter what company mandated standards are in place (Hix & Hartson, 1993). HCI guidelines are not limited to blue chip companies and Silicon Valley software developers, either; the European community has also recognized the requirement for common guidelines.

In response to the need for common visual display terminals (VDT's) in the European Banking and Economic Area, European Community members transformed a previously human factors related "minimum safety and health requirements directive" into national law. They have gone one step further by requiring software developers, who may lack knowledge in the area of human factors, to utilize design-aid software tools that incorporate built-in human factor guides and testing criteria (Reiterer, 1993).

Even after subscribing to HCI guidelines, some experts believe that we have not evolved from our early non-GUI days of computing. Raskin (1997) explains that our present systems are as large, complex, and nightmarish as the mainframes they first displaced; he adds that to be a "power-user" one is expected to know, on average, over three hundred settings of the system he is using.

C. BACKGROUND

1. LCC Software Design Processes

The previous Loosely Coupled Components Software design process was simple. When a new idea for a map-based OR tool was discovered, it was immediately coded for proof-of-concept. The process allowed little or no human factors application until after the code was shown to work. The outcome of this process has been a sound OR tool that only a few people can utilize. Some of the user difficulties are discussed later in this chapter. Figure 1 shows the design process used prior to this thesis.

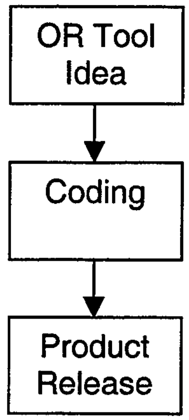

Figure 1. Existing LCC Software Design Process

The key to a successful and usable piece of software is incorporating human factors at the start of the design process. Modeled after Lim and Long's (1992) Structured Human Factors Design Framework, figure 2 shows an adapted version for the LCC research group.

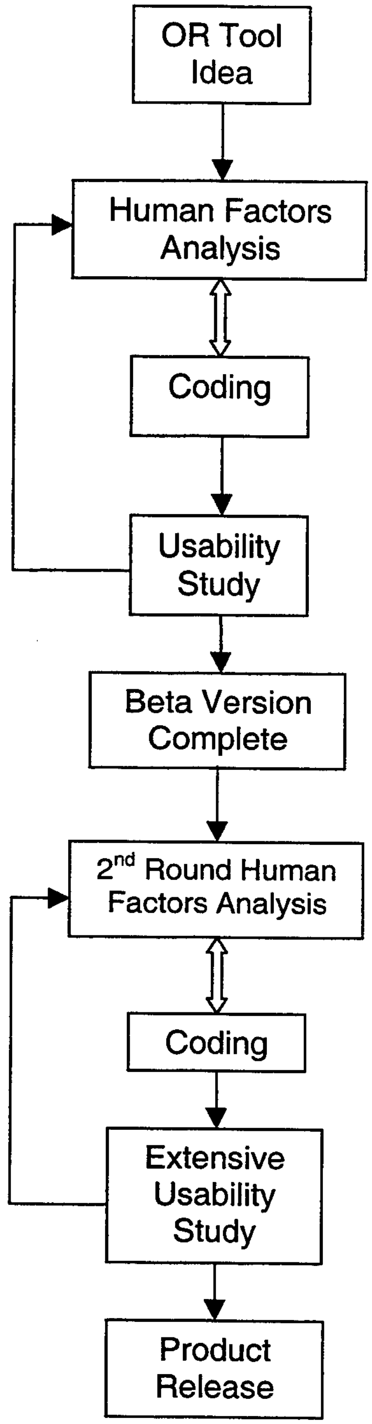

Figure 2. Improved Software Design Process

2. Current Information Display Systems Research

The Defense Advanced Research Projects Agency (DARPA) is researching ways to provide an integrated display and analysis tool to military commanders to aid decision making abilities via the Command Post of the Future (CPOF) program. The Land Warrior 2000 project is investigating wirelessly networked wearable-computers and associated displays for use by individual soldiers to increase their combat effectiveness. The LCC project is developing methods to loosely connect various Commercial Off-The-Shelf (COTS) components to create military systems for mission planning and execution that contain the capabilities envisioned by Joint Vision 2010.

a) DARPA's Command Post of the Future

DARPA's CPOF project is to develop advanced technology to create an adaptive, decision-centered, visualization environment for the future commander with the end goal of doubling the speed and quality of command decisions while cutting the required support staff in half (Page, 2000). Page, project manager of the CPOF program, further states, "As current technology floods the military commander with messages, images, and data, he will require larger staffs and more computers to process, interpret, integrate, and understand the incoming information streams (Page, 2000, p.1)."

Recognizing the human difficulty in processing large volumes of information at high rates, DARPA is incorporating various advances in Human Computer Interaction (HCI) technologies into its design.

Some of these technologies include GUI-based 3D visualization, interactive 3D techniques, Natural Language processing, and Knowledge Base querying

(Despain & Westervelt, 1997). They are also investigating human-computer interfaces that go beyond current GUI technology. Some examples include the creation of a "cyber-warrior," or computer-enhanced soldier, who could utilize visual cortex implants, vibration, temperature, eye-trackers, voice control, data gloves and intelligent user interfaces.

b) U.S. Army's Land Warrior 2000

In 1991, an Army Science Board Study recommended that the soldier be treated as a "complete fighting system;" this recommendation resulted in the initiative known as the Soldier Integrated Protective Ensemble (SIPE). After proof of concept, the SIPE Program evolved into the Land Warrior (LW) program in July 1995 and has since become the Land Warrior 2000 (LW2K) program. The LW2K program integrates a computer and a soldier into one networked fighting system. By combining advances in computer and communications technology, inexpensive COTS hardware, and advanced weapons aiming systems, the Army plans to employ each networked soldier as a complete weapons platform. (Jette, 1999)

The soldier will access his computer-enhanced system via the GUI on his handheld flat panel display or its near-future replacement, a helmet-mounted monocle. The Army plans to display digital messages, video, thermal site imagery, graphics, warning messages, and navigation information on either the monocle or the handheld panel.

c) NPS's Loosely Coupled Components

The Naval Postgraduate School's Operations Research Department began researching CPOF ideas and Land Warrior's networking concepts in 1996 with an Operations Research look at decision aids, electronic cartography, and security. The primary goal of the LCC project is to design, develop, and demonstrate decision support systems for military planning, execution, and training using COTS technology from the fields of wireless networking, Java©-based object-oriented programming, portable information display systems, war-fighting training systems, and mission planning tools (Bradley, Buss, & Shaw, 1998). These LCC objectives are achieved through a powerful object-oriented software concept to which new software modules and COTS hardware can be added and removed seamlessly via the Internet or wireless LAN. Some of the COTS equipment includes Palm IIIx™ PDA's, Casseopias™, Libretto™ palmtops, bar-code readers, Lucent™ WAVELAN cards, and global positioning systems.

The power of object-oriented programming using the Java programming language lies in platform independence and dynamic loading. Platform independence allows software to be "written once, [and] run anywhere" (Linden, 1997). Dynamic loading allows even the least capable computer to conserve memory by downloading and running software only when needed and then purging it upon completion.

Platform independence and dynamic loading are relatively new in military software design. Current military software design does not incorporate platform independence. It relies on a team of contracted software engineers who develop different versions of the same software tailored to meet the varying computing requirements of the military user. The Aegis computer software on U.S. Navy cruisers and destroyers best exemplifies this method of software design. As the ship's combat computer hardware is upgraded in staggered fashion throughout the fleet, it requires a new software baseline version. These differences in software baselines can limit the interoperability of ships employing the Cooperative Engagement Capability (CEC), which shares fire-control information between ships for ballistic missile engagement.

Dynamic loading is also an under-utilized concept in the military. The LW2K program will be the first to incorporate the ability for a minimally capable system to download programs, similar to Internet applets, as needed from network databases and then to purge them upon task completion. Examples of possible programs include optimal track routing, logistics calculators, and automated re-supply software.

Combining the strengths of platform independence and dynamic loading via object-oriented programming is the first step to creating a powerful network of tactical military computers. The second step is a local area network. Both the LW2K and LCC project are investigating and utilizing current wireless network capabilities. The tactical benefits of wireless networks are high mobility, encrypted information flow, and seamless LAN-entry and -exit of portable systems. The following are just a few of the possible information flows the LCC project incorporates: updated unit positions, current orders, and decision aids to acquire locations of nearest supply and medical stations. None of these capabilities can be utilized without a reliable wireless network connecting up to hundreds of portable computers and a robust visual interface to put the information at the soldier's fingertips.

D. EXISTING LCC SOFTWARE

Loosely Coupled Components (LCC) software was developed through a series of Operations Research (OR) Master's Theses (Bilyeu, 1998; Hattes, 1999; Schrepf, 1999). As each student developed a new OR tool, their module was attached to the existing LCC software through a common button bar. The overarching software hub is Thistle.

1. Thistle

Schrepf (1999) developed Thistle to simulate and model movement of ground forces which assists commanders make decisions for routing of convoys. The three primary GUI design flaws identified in Thistle are: poor menu structure and *Iconongraphy*, poor use of *Screen Real Estate*, lack of *Positional Constancy*.

Schrepf's interface was designed as a programmer's device to incorporate various Java classes into one program. While it allowed users to initiate numerous Operations Research modules by pressing their associated buttons, it was not designed for the untrained.

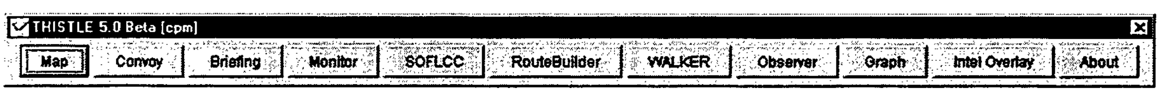

Figure 3. Thistle's button bar continued to grow as new tools were added to the program.

Every button has a text descriptor in place of a graphic icon. The human factor (HF) flaw in this design is two-fold. First, the user must read through the text of many of the buttons prior to finding the desired module. A better design would be to place the text in drop-down menus or use metaphorical icons. Second, the button bar is not organized by task or by commonality. Some of the modules use maps, even though there is a "Map" button on the bar. Once again, a multi-leveled drop-down menu would have been a better choice by organizing related modules in the same menu structure (Minasi, 1994). This menu should provide the basic structure of the software to the user without having to move a mouse or press a key. Thistle's menu structure is not intuitive to the user. Without any previous knowledge of what some of these buttons do, a novice user is left to experiment with each button until the desired feature appears.

If the user initiates several applications from Thistle's button bar, the computer monitor display becomes crowded and confusing as shown in figure 4.

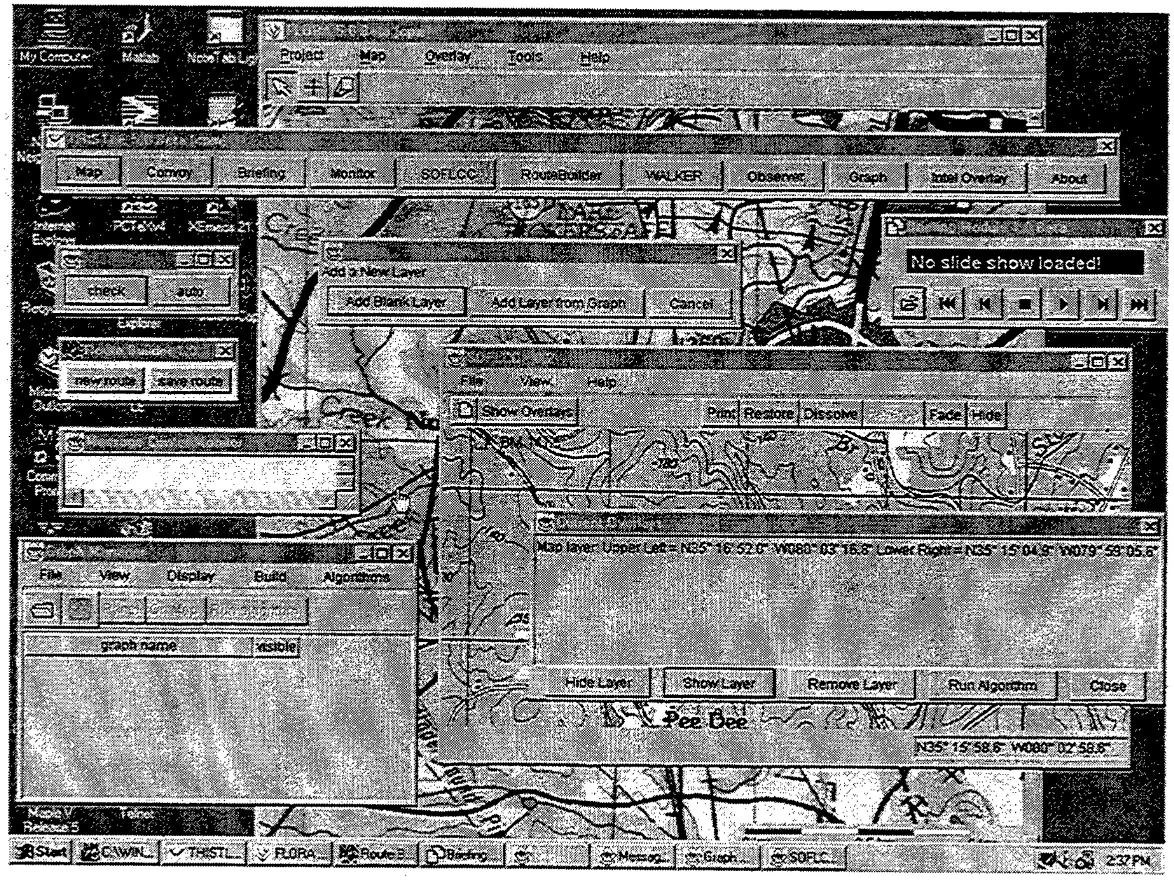

Figure 4. Thistle's Display with all features operating.

Figure 4 shows the second HF design flaw in the new software. Screen *real estate*, as many HF experts call it, is poorly managed in Thistle. Not only are there overlapping windows, but between the non-overlapped ones lie large areas of wasted space. The largest cause for the misused *real estate* is the software's ever-expanding interface design. Every new module opens its own window and piece of the user's visual field. A single or doubled window design would have be a cleaner and less confusing way of displaying data to the user.

The third interface design flaw was the lack of *Positional Constancy.* Positional constancy means the user can expect to find the same interface layout every time it is executed. Wickens, Gordon and Liu (1998) believe it is either through repetition and/or English language reading styles that users expect to begin any software application in the upper left-hand corner of the screen. Thistle utilizes multiple windows in various orders and positions that force the user to mentally track numerous module locations and eventually minimize and maximize module windows to locate them. The only result for novice users is frustration, confusion, and errors.

2. Flora

The second primary module in Thistle is a dynamic map and overlay display tool named Flora that allows users to plan tactical missions, analyze networking problems, plan convoy routing and even monitor GPS-networked units. Several tools are available to manipulate the displayed maps and overlays. One tool was the zoom-in / zoom-out feature available in the pull down menu that replaces the active National Imagery and Mapping Agency (NIMA) map with the next larger or smaller scaled image of the same geographic location. A "Grease Pen" *on-map* annotation tool is available for planning and analysis mark-ups. Users also have the option to load prepared overlays or create new ones with tools available in Flora. Overlays can consist of Grease Pen annotations, networking graphs with available networking algorithms, or unit symbology annotations for organic and multinational forces.

Flora's interface was the Loosely Couple Components' (LCC) first real start at incorporating map-based mission-planning features into one GUI. Many of its GUI design flaws limit its ability to be widely used by non-expert users. Some of it design flaws are cumbersome zoom-in / zoom-out features, unclear button functions, poor map field of view and scope, and poor map re-centering or dragging.

An example of Thistle's mapping display Flora is shown in figure 5.

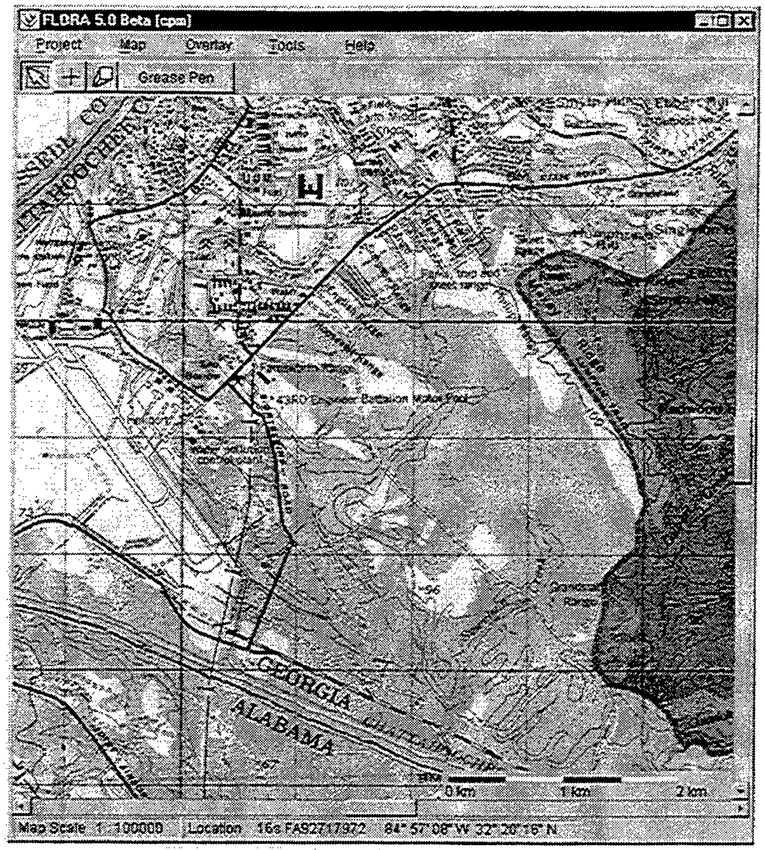

Figure 5. FLORA's map display was the first tool to include map annotation tools. The "Grease Pen" button launches a window with some basic annotation tools.

3. SOFLCC

The third major module in Thistle is SOFLCC which was developed to implement a platform independent mission planning and analysis system for the United States Special Operations Command (USSOCOM) (Bilyeu, 1998). SOFLCC combined the map display capabilities of Flora but added another unique feature - fading. The feature allowed the user to fade a map into an underlying satellite image that had been either geo-referenced at the same scale or "rubber-sheeted." The term rubber-sheet involves acquiring recognizable landmarks on the map, the same landmarks in an image, and then through mathematical algorithms, stretch one or the other until they are synchronous. The map in figure 6 has been partially "Dissolved" into an underlying satellite image. Dark patches are forested areas corresponding to the contoured hills on the map.

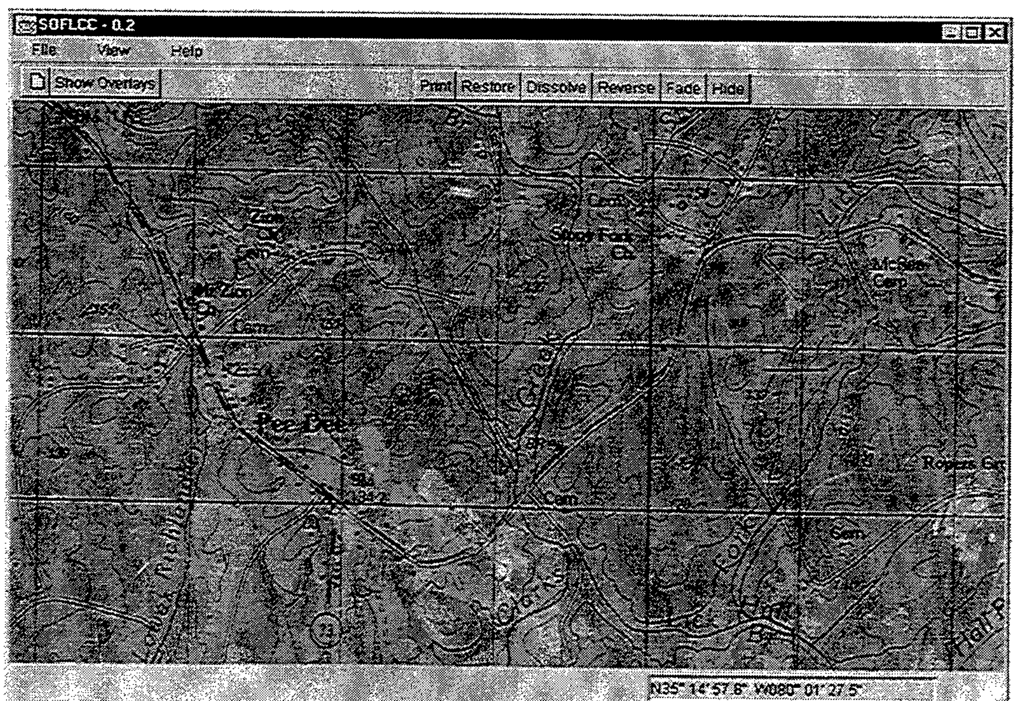

Figure 6. Special Operations Forces Loosely Coupled Components added the feature of blending satellite imagery with maps as shown here.

As with Flora, SOFLCC's design flaws lie in weak iconography and multiple windowing, and poor map manipulation. The user has to read the unevenly sized buttons until he finds the right one on the bar every time. A simple metaphorical graphic could increase the speed and accuracy of their use and improve user learnability.

According to Nolan (1989), icons need to be concrete-familiar (non-confusing and common) as opposed to abstract and unfamiliar (confusing and uncommon). Text-filled tool-buttons in SOFLCC are concrete-unfamiliar. Novice users can read the function of the buttons, but may not inherently know how to use them to accomplish a task.

Windowing again is a problem with SOFLCC. When the Show Overlays button is pressed, another window opens displaying all current overlays opened. And from that window, the user may choose from text-labeled buttons to "Hide Layers," "Show Layers," "Remove Layers," or "Run Algorithm." If "Run Algorithm" is pressed, another window opens to let the user load an algorithm. It is a complete surprise to a novice user that algorithms can even be run in SOFLCC or that they can be reached via the overlay buttons since there is no indication of such in the opening screen's layout.

SOFLCC fares even worse in its map manipulation. In short, there is none. The map itself is an overlay with no zoom capability at all. The user has no way of using the map for any purpose other than prepared overlays and algorithms.

4. LCC Software Usability Summary

Each piece of software was examined under the established guidelines set by the DoD HCI Style Guide (1994) and a variety of compilations by Schneiderman (1998), Mayhew (1992), and Brown (1989). Due to time limitations, only Iconography and Map Manipulation Flaws will be addressed in the interface redesign. All of the Operations Analysis tools developed in both Flora and SOFLCC have proven necessity in military planning and operations and will be coded into the new interface as time permits.

E. PURPOSE AND RATIONALE

This thesis proposes a software design process and a GUI designed under widely accepted HCI guidelines, to replace the existing LCC software. It is not the author's attempt to weaken the underlying power of any of the LCC programs, but strengthen them by folding them into an interface that is easy to learn, easy to use, and incorporates the features of all the programs. A usability study was conducted on the new GUI to determine its usability and to establish baseline data for comparison with future interface improvements.

The new system, Mapping, Information, Display and Analysis Systems (MIDAS) exploits the same Java features the existing LCC software does, while maintaining networked map-based mission planning tools. Due to the vast changes in the interface design, a comparative study between MIDAS and the old interfaces was not feasible and deemed unnecessary. Therefore, the study's scope was narrowed to the two major GUI improvements and their corresponding usability metrics: Iconography Recognition and Map Manipulation. The usability study measured learnability, memorability, and efficiency. It was hypothesized that MIDAS graphical user interface would be superior to the existing LCC graphical user interface software due to the adherence to human factors principles. Specifically, MIDAS incorporated drop-down menus and metaphorical icons to aid user readability, standardized mouse functions across all map-manipulating tools, and managed its screen real estate in a clear and simple manner.

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II. METHOD

A. MIDAS

Mapping, Information, Display and Analysis System is a software concept in re-designing existing LCC user interfaces for military mission planning utilizing the new LCC Software Design Processes shown in figure 2 and Appendix A. As a Java based program, MIDAS takes advantage of its object-oriented programming by incorporating existing Java classes from both Thistle/Flora and SOFLCC and leaving itself open-ended to the capability of importing new methods and modules via networks or the Internet. The largest contribution MIDAS should make to the LCC project is improving the usability of the map-based mission planning. MIDAS specifically addresses the three major flaws in Thistle/Flora and SOFLCC.

1. Iconography

The icons chosen for MIDAS follow accepted human factors guidelines for familiarity, visual and conceptual distinctness, design detail, and consistency in scheme (Mayhew, 1992; DISA 1994; DoD 1999). The images were chosen to help the user in maintaining context and orientation while reducing the requirements for memorizing commands and syntax (Brown, 1989). The icons for each button are displayed in table 1 with their associated functions.

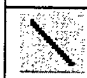
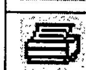
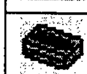
	Arrow	Restores mouse to default features
	Grab	Enables the mouse to "grab" the map and move it around the screen to re-center or adjust
	Magnify +	Zooms in on image with the "click" location as the new image's center
	Magnify -	Zooms out from image with the "click" location as the new image's center
	Text	Brings up text entry box to place text at the location of the mouse "click"
	Fade	A left "click" will merge the top image into the back image – a right "click," the opposite
	Line	Draws a line from a "click" and "drag" to a new point
	Ellipse	Draws a corner-anchored ellipse or "click"-centered ellipse if the Shift key is held
	Rectangle	Draws corner-anchored rectangle or "click" – centered rectangle if the Shift key is held
	Route	Places a route between two junction images
	Junction	Places a junction shaped object on the image
	Color Palette	Enables a color palette to choose the active color from
	Print	Sends the overlay to the default printer
	Erase	Clears all overlay objects from image
	Undo	Removes a single overlay from the image
	Restore	Restores a single overlay to the image

Table 1. MIDAS's buttons and their related functions

2. Multiple Widowing

Unlike Thistle/Flora and SOFLCC, MIDAS displays one resident window. Temporary windows include a file chooser and color chooser. The user may reposition and resize the GUI to fit the screen as necessary. MIDAS departs from Thistle in one other major feature – expandability. In Thistle, new OR concepts were added to the program by adding a new window and a new button on the command bar. As future features are added to MIDAS, they will only assume "real-estate" required for the feature's name on the menu bar. The feature's pull-down menu will cascade into the screen like other menus and disappear upon completion of a specified task. No additional resident windows will be generated by any menu item as in Thistle. Figure 7 is a screen shot of the opening view of MIDAS.

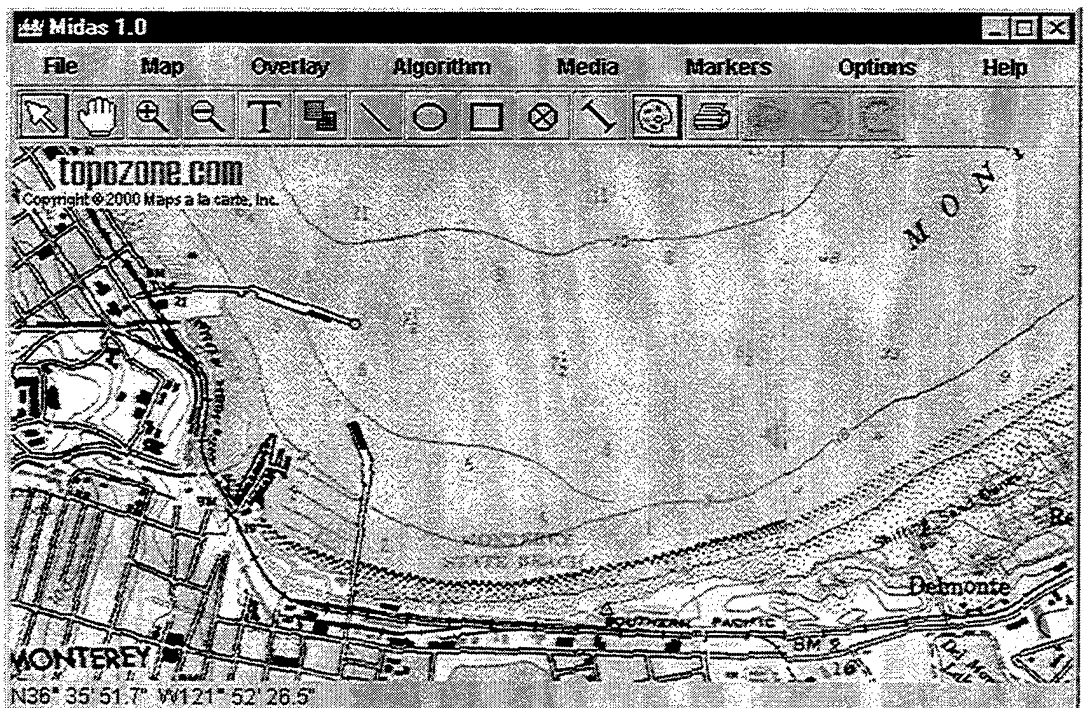


Figure 7. MIDAS starts with most map-base tools visible to the user. No further menus are required to begin work on a map.

3. Map Manipulation

Successful map manipulation in map-based systems relies on four basic points: image format, map movement, zoom, and map annotation.

a) Image Format (.gri)

The LCC concept requires MIDAS to be as flexible as possible with image formats and mixing thereof. Where some map-based systems require consistent use of one image type (i.e. .bmp, jpeg, .gif, .tif), MIDAS' image handling started at ground zero. The two characteristics of any map required for successful use are the image itself and at least two known coordinates on the image. By combining the two into a geo-referenced image, the result is useful for all map-based planning. MIDAS, from the outset, only accepts geo-referenced images (.gri) formatted files (Buss, 2000). This new format solves the problem of using any referenced or non-referenced image type (satellite, hyper-spectral, intelligence, topographic, radar, remotely piloted vehicle (RPV), hand-drawn, etc.) in MIDAS. Files with the .gri format are created by a Java class that imports an image, takes latitude and longitude coordinates from the user, and serializes them into an image with associated position tags. Upon importing or loading the image into MIDAS, the position tags are read which then transforms any pixel in the image to a latitude and longitude. Any annotations then made to any image are ported and resized, by latitude and longitude, to any other geo-referenced image that may overlap the same geographical area. This image format also has exciting possibilities in "rubber-sheeting" non-referenced intelligence images to known geo-referenced images providing mission planners another tool in analyzing images.

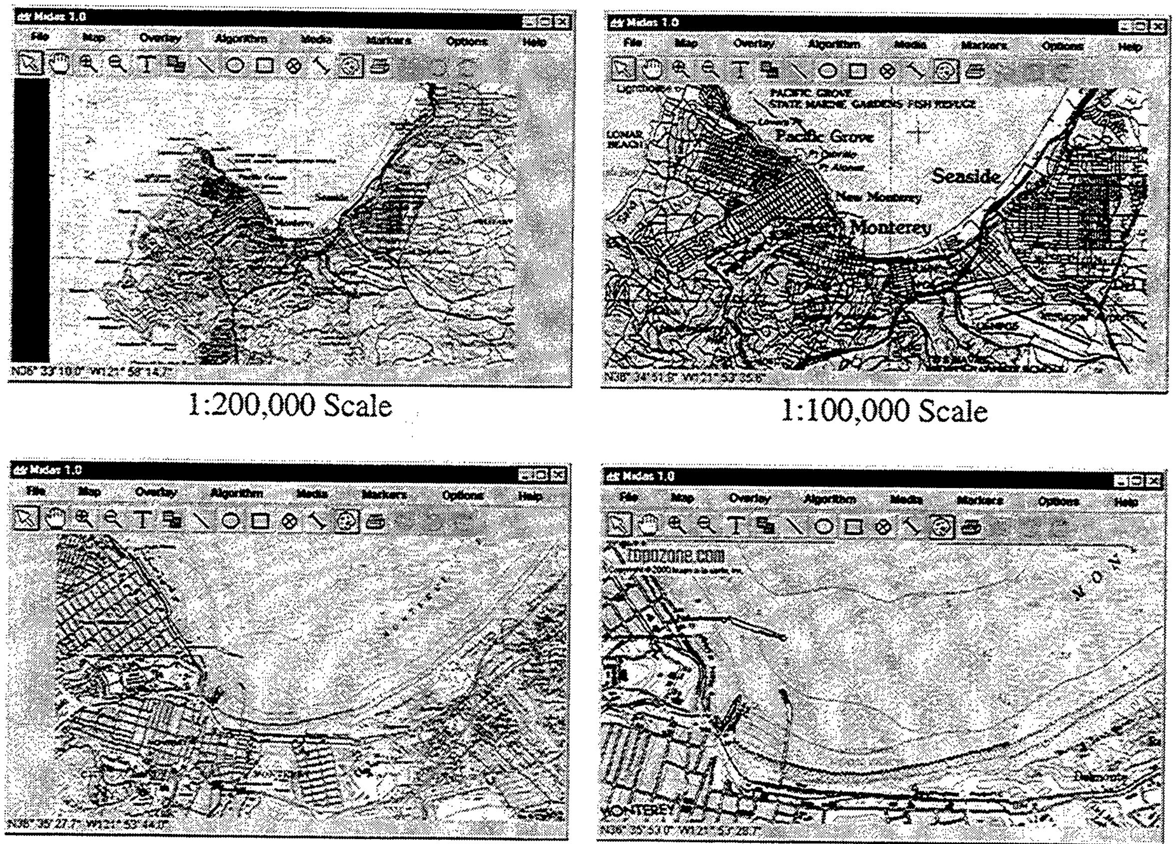
b) Map Movement

Map movement is handled by two basic actions. The first is instantiated by a right click of the mouse somewhere on the image. The result is re-centering the image at the location of the click.

The second map movement is instantiated by clicking the "Grab" icon which enables the mouse controlled drag mode. When the left mouse button is pressed in this mode, the image can be dragged by movement of the mouse and repositioned by releasing the mouse button.

c) Zoom

Two buttons – the Zoom-In and Zoom-Out, control MIDAS' zoom feature. As one can infer, the Zoom-In button replaces the current image with one of larger scale in the GUI pane. Zoom-Out completes the opposite function. To zoom in or out on an image, the user first mouse-clicks on either zoom-in or zoom-out icon and then a location on the image. The place selected on the image becomes the center of the new display. For the usability study, the zoom levels were limited to four scales. The four zoom levels are shown in figure 8. Other methods for improved zooming will be covered in the discussion chapter.



1:200,000 Scale 1:100,000 Scale

1:50,000 Scale 1:25,000 Scale

Figure 8. In its first version, MIDAS's zoomed images scale as determined by linking variously scaled maps of the same geographic area.

d) Map Annotation

For any map-based planning software to be effective, users must have the ability to annotate it. Thistle gave the user a "Grease Pen" tool allowing lines, circles, squares and symbols to be overlaid on the image. The same capability was incorporated into MIDAS in an improved fashion. Accompanying the mentioned functions, are three new tools: "undo," "restore," and "erase." These tools allow the user to make corrections to map annotations. User-added annotations are also geo-referenced to the image allowing lines and marks to overflow to new images of the same geographic area and be resized to match the effects of zoomed images.

B. USABILITY EXPERIMENT

1. Participants

Twenty participants volunteered for the usability study. Table 2 shows the breakdown of participants in the study.

User Type	USN	USA	USMC	DoD Civilian	Civilian	Foreign Navy	Totals
Male	7	6	3	1		1	18
Female	1				1		2
MAC	1						1
Windows	7	6	3	1	1	1	19
TOTAL	8	6	3	1	1	1	20

Table 2. Usability Study Subject Demographics

Sixty percent of the subjects reported previous use of map-based software. All had a neutral or positive attitude toward computer use. Average computer sessions per week were 15.2 with an average session length of 57 minutes.

Figures 9, 10, and 11 show computer-use demographics for subject sample.

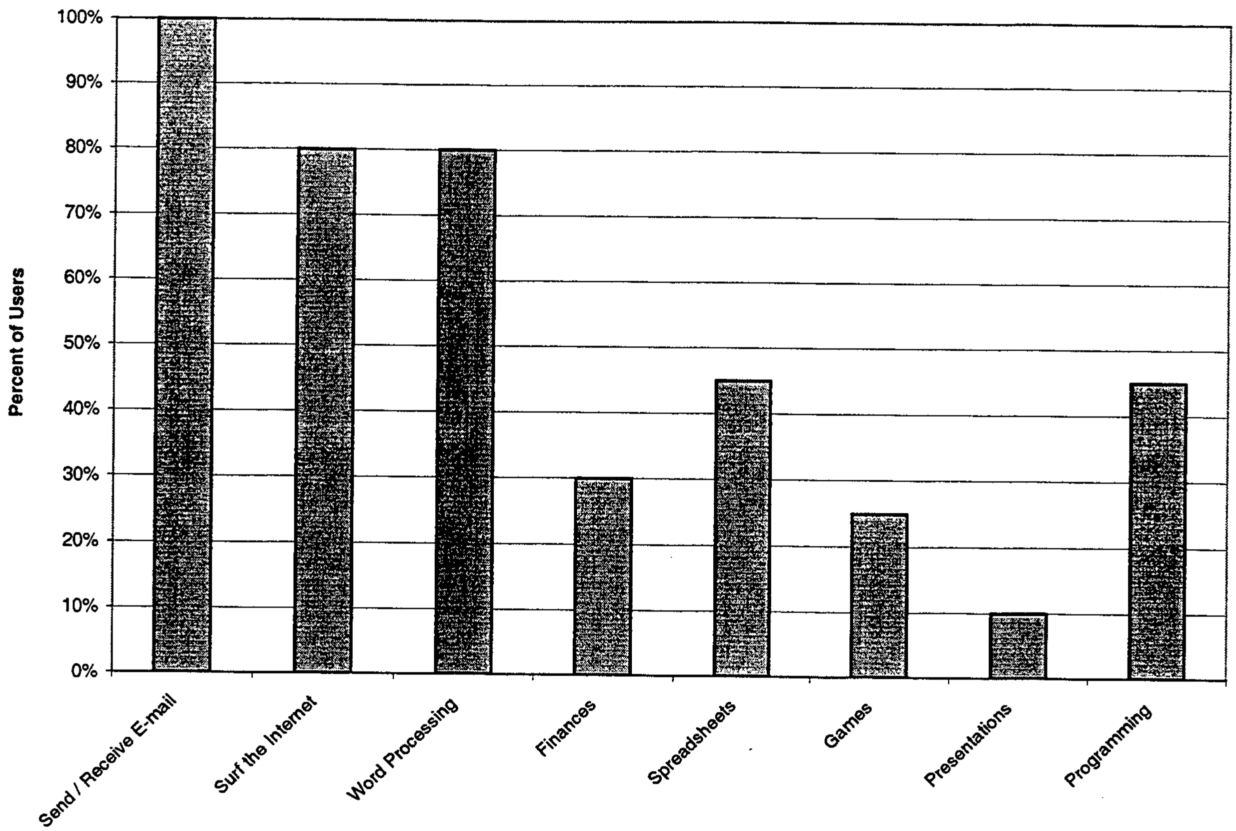


Figure 9. Participant's software application usage

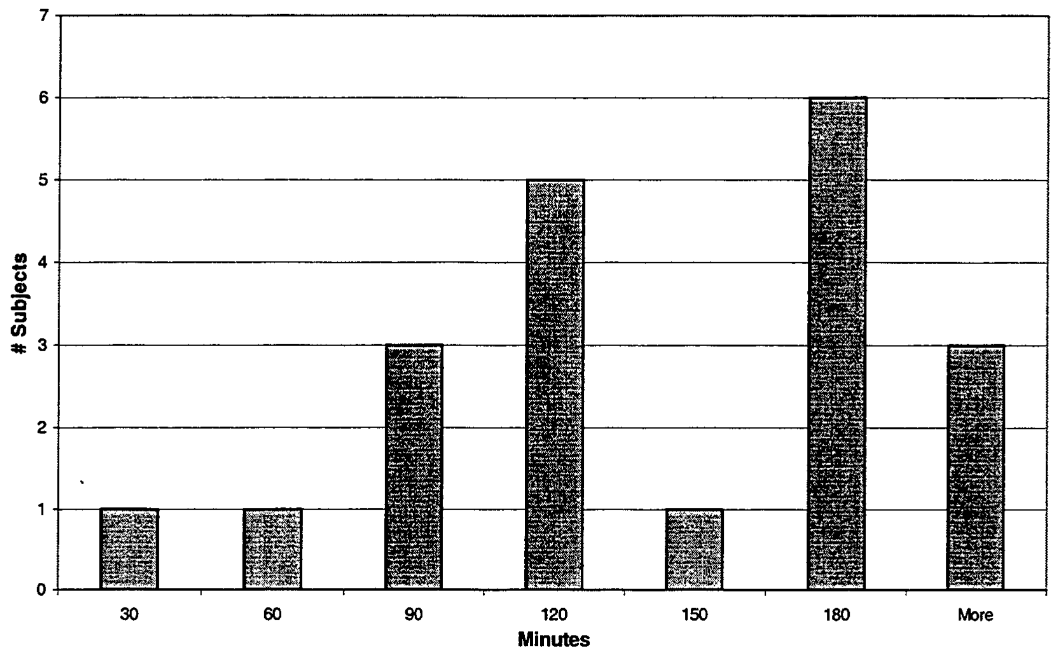


Figure 10. Computer Use Per Week (n=20)

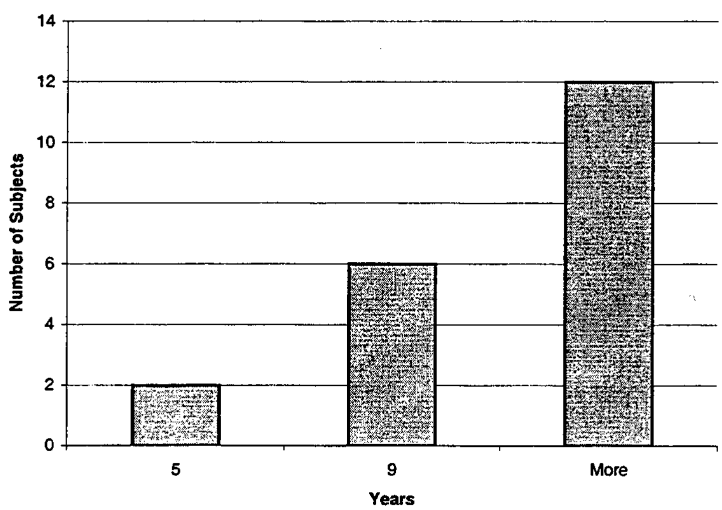


Figure 11. Years of Computer Experience (n=20)

2. Apparatus

Subjects were seated in front of a standard 19" (17.75" viewable) computer monitor set at 65,636 colors, 1024x768 pixels, 85Hz refresh rate, and font size *small*. The processor was a Pentium III 500 MHz with 128 MB RAM and equipped with a 104-key standard keyboard and an Intellimouse®1.1A PS/2.

A high-grade video recorder with audio was used to collect a record of each test session for additional information gathering on each subject. The video feed was broadcast to a High Definition Television to enable continuous visual test monitoring.

3. Software

MIDAS was written in Java 1.2.2 (Sun Microsystems, 2000) utilizing Borland® JBuilder3© and various text editors.

Icon images utilized by MIDAS were bitmaps produced by the author using Microsoft's® Paint© program and converted to Graphical Interchange File© (.gif) format using Microsoft's® Image Composer©.

4. Industry HCI Benchmarks

Industry benchmarks for usability vary between companies and applications; therefore it is difficult to find published success rates for task completion, icon identification, and memorability. In order to establish a qualified heuristic benchmark, several experts in the HF industry were consulted for their opinion as applicable to MIDAS and its usability study. The following personnel provided a consensus of acceptable usability benchmarks to compare MIDAS usability test data. Jose Arcellena is a Human Interface Specialist for the National Broadcasting Company Internet Inc. Peter

Bickford is CEO of Human Computing Consulting Firm and former HF specialist at Sun Microsystems. Dr. Mary Cwerwinski is the head of the Adaptive Systems Interaction Group at Microsoft. Donald Gentner is Senior Staff Engineer and Human Interface Designer at JavaSoft, Sun Microsystems. John Pane is a Graduate Assistant to the Computer Science Department, Carnegie Mellon University.

5. Procedure

Subjects were asked to read and sign various consent and experiment information forms as well as a background questionnaire (Appendix B) based on Rubin's questionnaire for computer usability studies (1994). Data gathered during the experiment was annotated on the Data Collection Sheet found in Appendix C.

After all forms were completed, subjects were moved to a half-walled cubicle where the software was already running and seated at the computer station. They were then asked to describe the function, by iconography only, of selected buttons annotated in Appendix C. Subjects were then asked to enable the tool tips option and review the function of any button they were unsure of. Subjects were then asked to complete nine more pre-determined tasks also shown in Appendix C. Each of the tasks addressed the user's ability to complete map-manipulating functions with no prior training or exposure to the interface.

Each experiment session lasted approximately 15 minutes. Upon completion of the tasks, subjects were allowed to ask questions to clarify any difficulties and make comments regarding the program's interface or future use.

To test for Memorability of MIDAS' GUI, ten subjects received an icon recognition test (Appendix C) approximately one week after their initial testing. Subjects were asked to provide the function of the same buttons that were tested in the initial test.

User comments and recommendations for improved icons were annotated and are discussed in the Results.

III. RESULTS

A. LEARNABILITY

Learnability was tested using two methods. The first was straight identification rates compared to industry standards. The second method determined that MIDAS's icon identification rates are predictable.

1. Identification Rates

The industry standard for icon identification rates is 70% for initial contact (Czerwinski, personal communication, 11 May 2000, Bickford, personal communication, 11 May 2000). This standard was used to establish which icons in MIDAS' GUI required redesign. Figure 12 shows the icon identification rates for all twenty subjects across all thirteen icons.

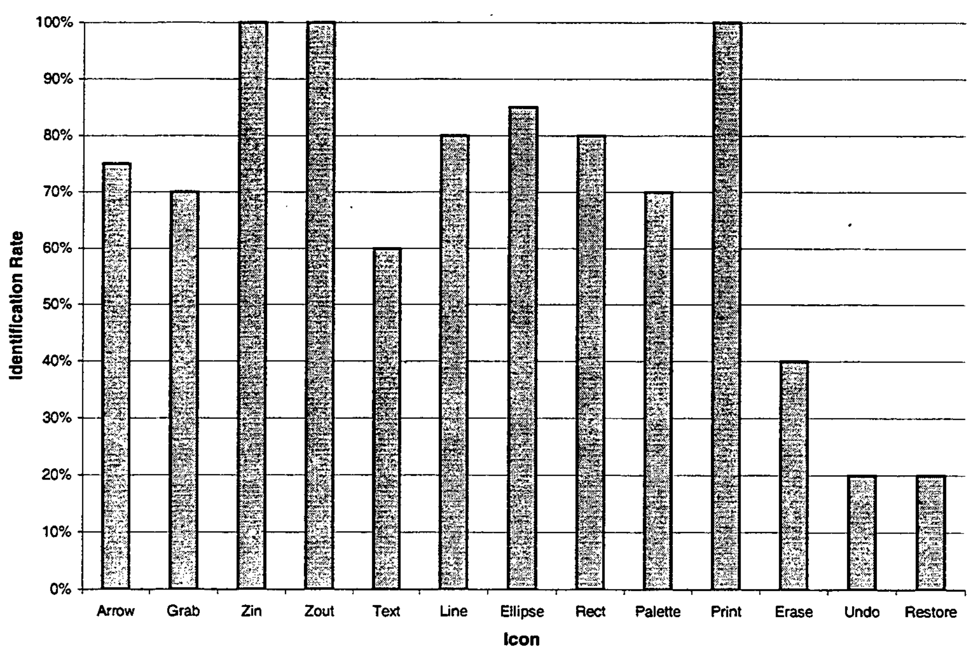


Figure 12. Icon Identification Rates (n=20)

The four icons identified as having poor learnability are Text, Erase, Undo and Restore, each of which scored below the 70% identification rate. The most common icon misidentifications or responses for the four icons are summarized in Table 3.

Button	Response	Rate
Text	"Don't know"	30%
Erase	"3-D drawing"	50%
Undo	"Rotate Left 90°"	70%
Restore	"Rotate Right 90°"	70%

Table 3. Misidentification Responses and Associated Rates

The icons' poor learnability may be attributed to two reasons. First, they did not provide enough visual cues to the user to establish a metaphor for their use. Second, they matched too closely to icons in other software that perform very different functions. Third, they did not match icons from other software that perform the intended functions. The four poor icons should be redesigned and re-tested utilizing the study's feedback and compared to benchmarks established.

2. Icon Identification Predictability

Learnability was also examined to determine if subjects' scores were dependent upon his/her demographics. A least squares regression model was calculated to determine if subjects' scores for icon identification were influenced by demographics (Agresti, 1990, Cook & Weisberg, 1999). Subject's scores were determined to be dependent upon demographic data via the following statistically significant model with an alpha level of .05 ($\underline{F}$ (3,15) = 4.03, $\underline{p}$ = .0275). These results show that icon identification for a similarly demographic sample can be predicted by knowing the average length of their computer session, how many sessions a week, and number of years computer experience.

$$Score = 4.6410 + (.0173) \times (Length) - (.6045) \times (Session) + (.5930)(Years)$$

The regression model was validated using the metrics and test statistics shown in Table 4. Supporting graphs are in Appendix E.

Regression	p = .0275
R^2	.4464
Non-Constant Variance	p = .303
Curvature [fitted values]	p = .243
Curvature [Length]	p = .957
Curvature [Session]	p = .772
Curvature [Years]	p = .961

Table 4. Regression Statistics

These results are important for two reasons. First, they show future interface designers the demographics that determined successful identification in this sample population. Second, they provide the designer guidance to tailor the interface for a target population or take steps to broaden the identification rate across a larger demographically diverse sample.

B. MEMORABILITY

The metric for determining Memorability was a second icon identification test one week after the initial exposure to the icons. The acceptable industry success rate for Memorability is 100% (Gentner, personal communication, 12 May 2000, Arcellena, personal communication, 12 May 2000, Pane, personal communication 12 May 2000).

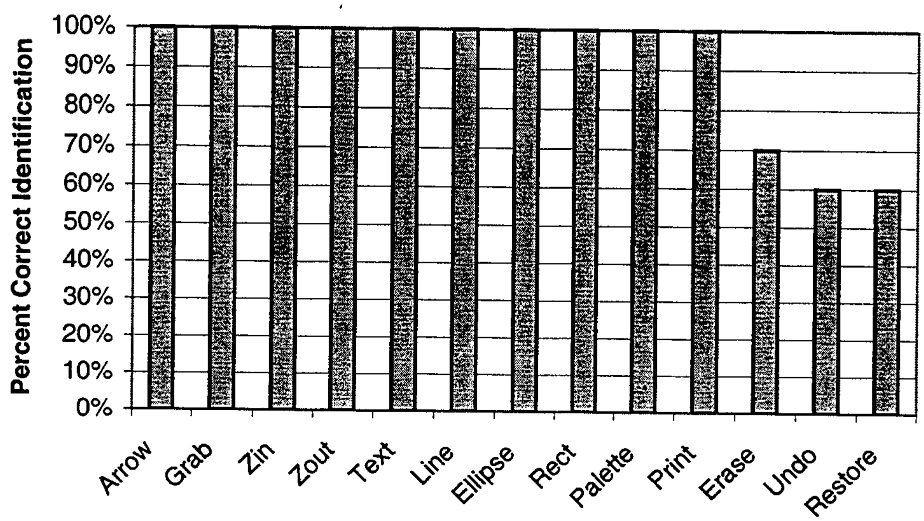


Figure 13. Icon identification success rate for Memorability

The majority of MIDAS' icons scored well in Memorability. After only one exposure to the icons, 10 of 13 icon recognition rates were 100% when tested one week later. Icons with problems, Erase, Undo, and Restore, were well below the standard of 100%. Their lower rates are due to the same reasons they had poor Learnability. The icons were confused with icons already learned from other software that complete very different functions than those in MIDAS. After three new icons are shown with acceptable Learnability, future studies should test shorter and longer in-between-use times. These results show the majority of images selected for the button bar are easy to remember even without consistent use.

C. EFFICIENCY

Overall, MIDAS has an efficient interface. With no prior training, subjects are able to quickly become productive scoring above 90% for all map manipulation tasks. Figure 14 shows success rates for the ten map manipulation tasks described in Appendix C.

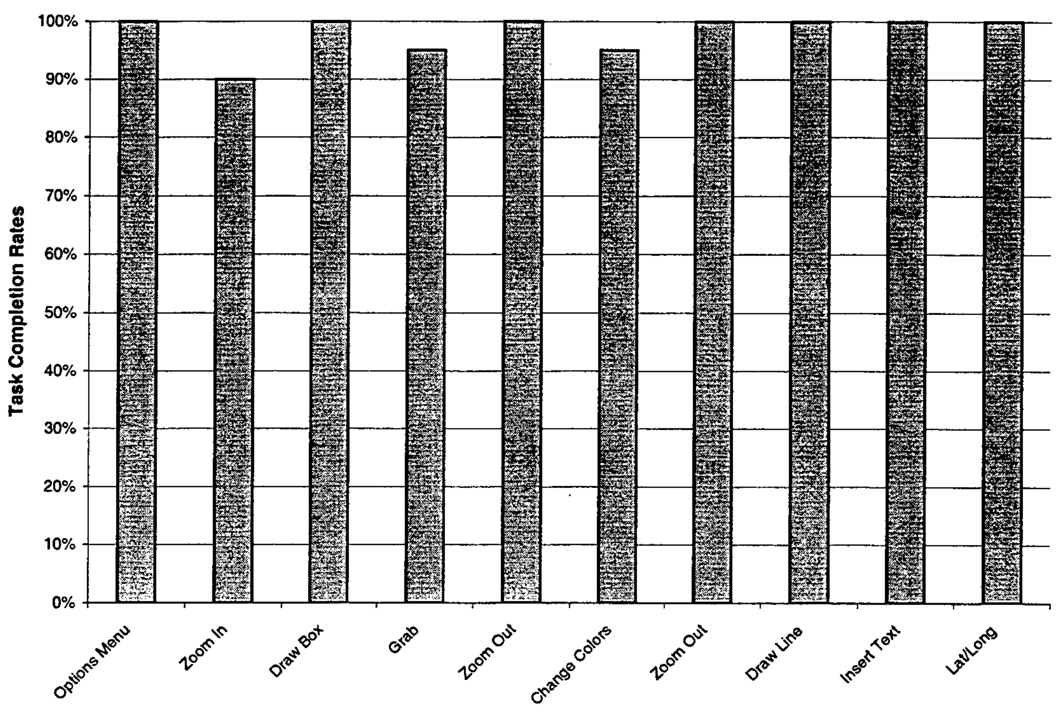


Figure 14. Map Manipulation Task Success Rates (n=20)

Though users could not identify the function of all of the icons with the tool tips feature disabled, they were able to successfully complete the tasks with tool tips enabled. This result shows the success of the interface design concept that gives the user the ability to add helpful information to the interface to improve efficiency. The ability to turn the tool tips off also allows experienced users eliminate possibly annoying clutter.

Future work in Efficiency should focus on an in-depth task analysis or scenario driven task list. Many subjects did request to use the software for personal or school-related work – a subjective sign that the interface was easy to learn and use.

IV. DISCUSSION

The goals defined at the onset of this thesis were to produce a quality easy-to-use graphic user interface (GUI) for map-based mission planning and conduct a usability test to determine its design success. The usability study identified some weaknesses in icon design that in the next version of MIDAS will be improved and re-tested. The weakness were not strong enough to adversely affect the overall success of MIDAS's interface.

MIDAS successfully combines many of the proven tools from existing Loosely Coupled Components software into one streamlined design while incorporating the strong design points of established human factors guidelines. With continued GUI improvement and testing, MIDAS will grow to become a powerful and portable map-based mission-planning tool. Recommended improvements in MIDAS' interface can now be tested against the benchmark established in this thesis.

A. RECOMMENDATIONS

MIDAS will continue to evolve under the guidance of the LCC research group. As new map-based Operations Research tools are developed, they must be subjected to the new Software Design Process and must comply with established DoD (1999), DISA (1994) and Industry HCI standards. Technology will continue to evolve bringing smaller displays and unique pointing devices to the doorstep of LCC. The research group must maintain an understanding of the human factors involved to successfully exploit the capabilities of these emerging technologies.

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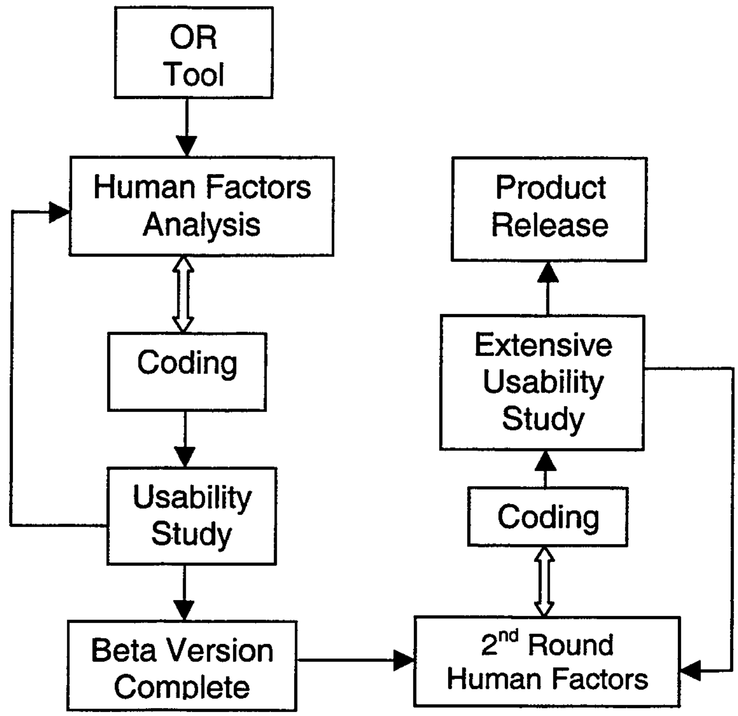
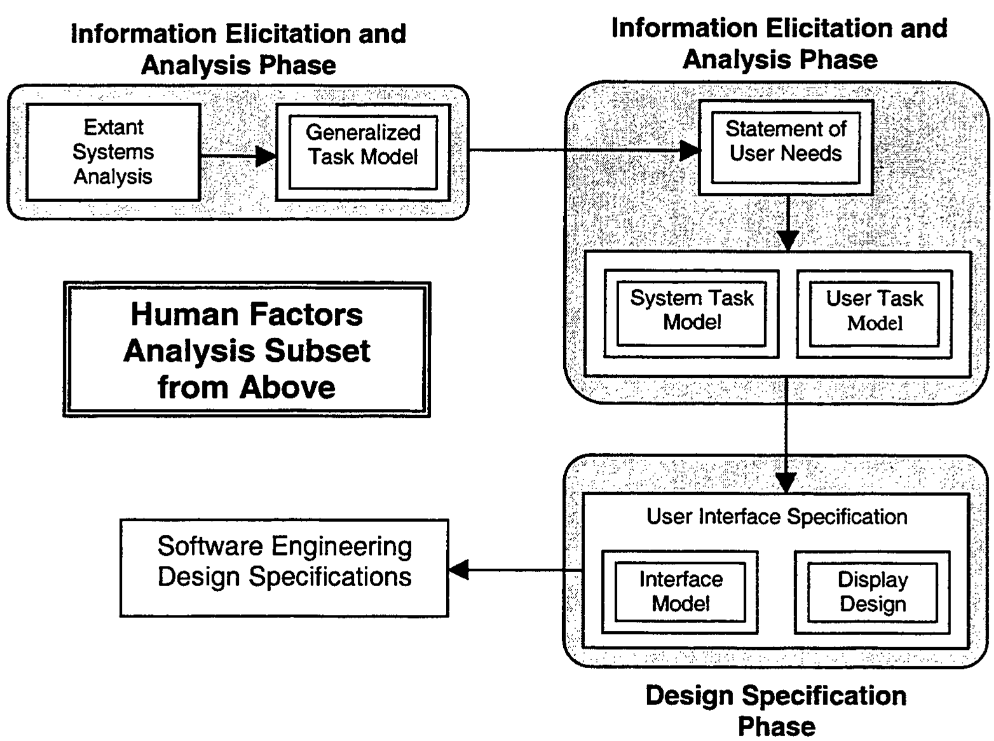
APPENDIX A. LCC SOFTWARE DESIGN PROCESS





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APPENDIX B. MIDAS SUBJECT QUESTIONNAIRE

1. What is your age? (20-25) (25-30) (30-35) (>35)

2. Male or Female? M F

3. Occupation? ____________________

4. If military, what rank and branch? ______________________

5. Highest Grade Completed?

   12 Assoc. BA/BS MA/MS MD/Ph.D.

6. Which is your dominate hand? Left Right

7. Are you currently experiencing any problems that impair your ability to use a computer?

   a) Yes b) No

If yes, what are they?____

8. How many times do you use a computer a week? 1-5 5-10 10-15 >15

9. What is your most common computing session length?

   <10min 10-30min 30-60 min 60-90min >90min

10. How many sessions of this type do you have a day?

    a) 1
    b) 2
    c) 3
    d) 4
    e) >4

11. Which of the following applications do you most often use on a daily basis? (circle as many as necessary)

a) Send / Receive e-mail
b) Surf the Internet
c) Word Processing
d) Finances
e) Spreadsheets
f) Games
g) Presentations
h) Programming
i) Other ______________________________

12. What operating system do you primarily use? (circle more than one if needed)

a) Windows 9X, NT, 2K
b) Mac
c) Linux
d) Unix

13. How many years have you been actively using a computer?

a) < 1
b) 1-3
c) 3-5
d) 5-9
e) > 10 yrs.

14. Have you used map-based software? (commercial, military, Internet, etc.)

a) Yes
b) No

15. Are you geographically familiar with the Monterey Peninsula?

a) Yes
b) No

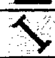
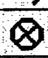
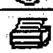
16. What is your attitude toward computer use?

a) Positive
b) Indifferent
c) Negative

APPENDIX C. MIDAS DATA COLLECTION SHEET

PART 1: ICONOGRAPHY

"What do you think the functions of the following icons are?

Icon	Correct (✓)	Incorrect (✓)	Accepted Answers
			pointer, arrow, mouse control
			grab, drag, move
			zoom in, make larger
			zoom out, make smaller
			add text, annotate, add words, label
	NOT TESTED		
			draw line
			draw circle, draw ellipse
			draw box, draw rectangle
	NOT TESTED		
	NOT TESTED		
			change color
			print, print image, print map
			erase, remove
			undo, undo last
			restore, restore last, return, undo an undo

PART 2: MAP MANIPULATION

Function Tested	Task	Completed (✓)	Incomplete (✓)	Assistance Required (Y/N)
Options Menu	"Turn on the tool tips option."			
Zoom In	"Zoom in until you find Naval Postgraduate School."			
Draw Box	"Draw a box around the entire School."			
Grab	"Grab the map and re-center to place wharf area in the center of the screen."			
Zoom	"Zoom in on the Northern Wharf."			
Change Colors	"Change active color to red."			
Draw Circle	"Draw a circle around the end of the pier."			
Zoom Out	"Zoom out until you see both Lover's Point and the Municipal Airport."			
Draw Line	"Draw a line between the airport and Lover's Point."			
Insert Text	"Label the Monterey Bay."			
Lat / Long Readout	"What is the Lat / Long of Herman Hall?"			

APPENDIX D. FOLLOW-UP ICON RECOGNITION TEST

MIDAS v.1 Usability Test Data Collection Sheet
Part Two

In two or three words, what do you think the functions of the following icons are?

Icon	Answer
	
	
	
	
	
	
	
	
	
	
	
	
	
	
	
	

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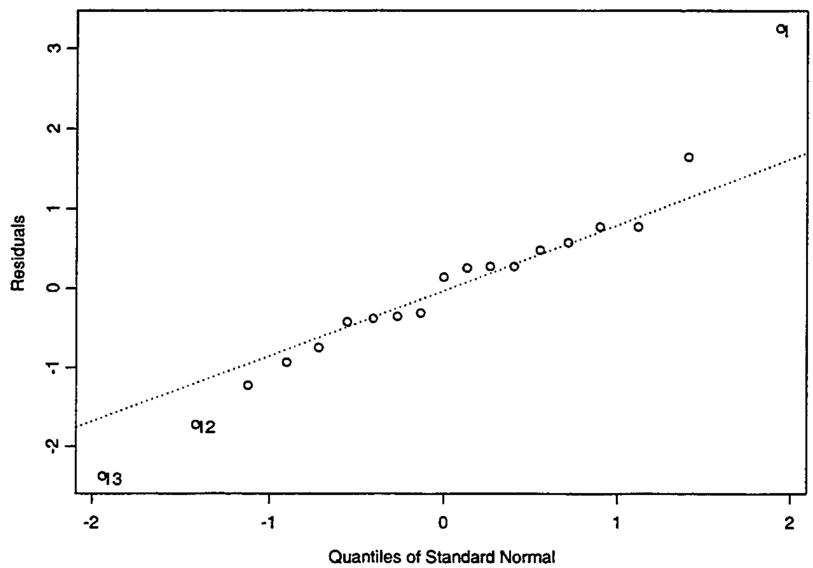
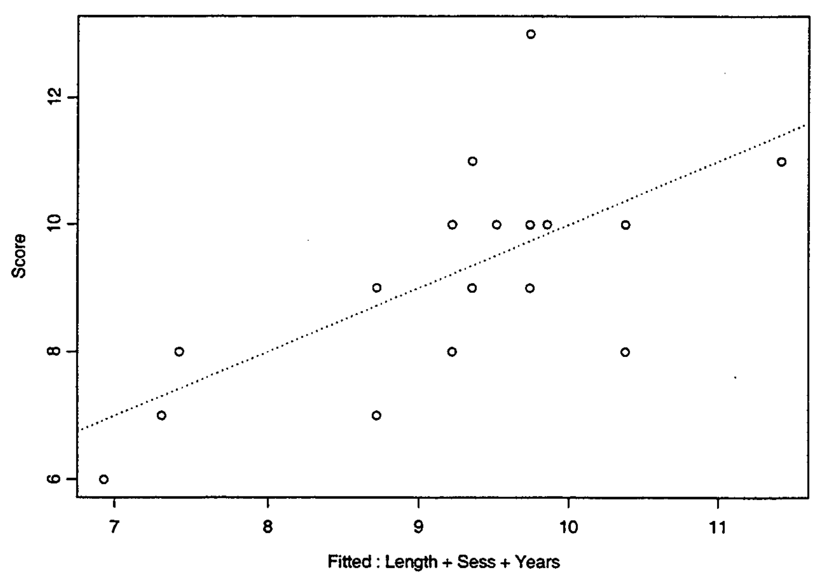
APPENDIX E. REGRESSION SUPPORT

$$Score = 4.6410 + (.0173)\times(Length) - (.6045)\times(Session) + (.5930)(Years)$$





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LIST OF REFERENCES

Agresti, A, (1990). Categorical Data Analysis, John Wiley & Sons, Inc., New York, New York.

Bilyeu, A. L. (1998). Concept for a Special Operations Planning and Analysis System, Master's Thesis, Naval Postgraduate School, Monterey, California.

Bradley, G., Buss, A. & Shaw (1998). An Architecture for Dynamic Planning and Execution Using Loosely Coupled Components, Naval Postgraduate School Research Letter, 8, 1-7.

Brown, C.M. (1989). Human-Computer Interface Design Guidelines, Ablex Publishing Corporation, Norwood, New Jersey.

Buss, A. H. (2000). A Note on Geo-Referenced Images, Unpublished manuscript. Department of Operations Research, Naval Postgraduate School, Monterey, CA.

Card, S., Moran, T. P. & Newell, A. (1983) The psychology of human-computer interaction, Lawrence Erlbaum Associates, Hillsdale, New Jersey.

Chairman of the Joint Chiefs of Staff (1996). Joint Vision 2010, , Pentagon, Washington, D.C.: Author.

Defense Information Systems Agency (1994). Department of Defense Technical Architecture Framework for Information Management, Volume 8: Department of Defense HCI Style Guide, (v2.0, 30 June 1994).

Department of Defense (1999). Design Criteria Standard: Human Engineering, (DoD Publication No. MIL-STD-1472F), Washington, D.C.: Author.

Despain, A., & Westervelt, R. (1997). High Performance Human-Computer Interfaces, Project Summary Booklet, JASON Program Office, The MITRE Corporation, sponsored by DARPA.

Devore, J. L. (1995). Probability and Statistics for Engineering and the Sciences, 4th ed. Brooks/Cole Publishing Company, Pacific Grove, California.

Dix, A. J., Finlay, J. E., Abowd, G. D. & Beale, R. (1998). Human-Computer Interaction, Prentice Hall Europe.

Halasz, F., & Moran, T. P. (1982). Analogy Considered Harmful, Proceedings of Human Factors in Computer Systems, pp. 383-386, Washington, D.C.: National Bureau of Standards.

Hattes, K. A. (1999). Special Operations Mission Planning and Analysis Support System, Master's Thesis, Naval Postgraduate School, Monterey, California.

Hefley, W. E., Buie, E. A., Lynch, G. F., Muller, M. J., Hoecker, D. G., Carter, J., & Roth, J. T. (1994). Integrating Human Factors With Software Engineering Practices, Proceedings of the Human Factors and Ergonomic Society, 38, 315-323.

Hix, D. & Hartson, R. H. (1993). Developing User Interfaces Ensuring Usability Through Product & Process, John Wiley & Sons, Inc., New York, New York.

Jette. (1999). Land Warrior Technology Interests, MS Power Point Presentation, SY Technology Inc., U.S. Army Soldier Systems Center, Natick, MA.

Lim, K. & Long, J. (1992). A Method for (Recruiting) Methods: Facilitating Human Factors Input to System Design, Proceedings from Computer-Human Interaction CHI 92, 5, 549-556.

Linden, P. van der. (1997). Not Just Java, Sun Microsystems Inc., Mountain View, California.

Lund, A., & Tschirgi, J. (1991). Designing for People: Integrating Human Factors into the Product Realization Process, IEEE Journal on Selected Areas in Communications, 9, 496-500.

Mayhew, D. J. (1992). Principles and Guidelines in Software User Interface Design, Prentice Hall, Englewood Cliffs, New Jersey.

Microsoft (1998). Microsoft Usability: Making It Easier for Everyone, White Paper, [http://www.microsoft.com/PressPass/features/1998/5-19usewp.asp].

Minasi, M. (1994). Secrets of Effective GUI Design, SYBEX, Alameda, California.

Nielsen, J. (1999). Heuristic Evaluation, Usability Inspection Methods, John Wiley & Sons, New York, New York.

Nielsen, J. (1993). Usability Engineering, Academic Press, Cambridge, Massachusetts.

Nielsen, J. & Molich, R. (1990). Improving a Human-Computer Dialog, Communications of the ACM, 33, 338-348.

Nolan, P. R. (1989). Designing Screen Icons: Ranking and Matching Studies, Proceedings of the Human Factors Society 33rd Annual Meeting, 33, 380-389.

Page, W. (2000). Command Post of the Future (CPOF) *Program Description*, (DARPA Publication No. BAA-98-27), Washington, D.C.: U.S. Government Printing Office.

Raskin, J. (1997). Looking for a humane interface: Will computers ever become easy to use?, Association for Computing Machinery, Communications of the ACM, 40, 98-101.

Reiterer, Dr. H. (1993). The Development of Design Aid Tools for a Human Factor Based User Interface Design, Proceedings of the International Conference on System Engineering in the Service of Humans, 4, 361-366.

Rubin, J. (1994). Handbook of Usability Testing, How to Plan, Design, and Conduct Effective Tests, John Wiley & Sons, Inc. New York, New York.

Schrepf, N. J. (1999). Visual Planning Aid for Movement of Ground Forces in Operations Other Than War, Master's Thesis, Naval Postgraduate School, Monterey, California.

Shneiderman, B. (1998). Designing the User Interface – Strategies for Effective Human-Computer Interaction, Third Edition, Addison-Wesley Longman Inc., Menlo Park, California.

Sun Microsystems (2000). Java Development Kit v 1.2.2, [http://java.sun.com/products/jdk1.2/].

Wickens, C. D., Gordon, S. E., & Liu, Y. (1998). An Introduction to Human Factors Engineering, Addison-Wesley Education Publishers Inc., Menlo Park, California.

Wozny, L.A. (1989). The application of metaphor, analogy, and conceptual models in computer systems. Interacting with Computers, 1, 273-283.

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