DEVELOPING HUMAN FACTORS DESIGN PRINCIPLES FOR INFORMATION DISPLAY SYSTEMS IN AIR TRAFFIC CONTROL

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An Information Display System (IDS) provides access to many types of information. It consolidates data to one source and eliminates the need for multiple displays. An IDS provides a logical structure and uses a standardized information display format. We present a set of design principles for IDSs in Air Traffic Control (ATC). We conducted an investigation of information and usability requirements in each of the ATC domains. Based on the investigation and on existing design guidelines and standards, we developed design principles that capture the critical components of designing an effective IDS for ATC. In order to be useful and usable, an IDS and the information it contains should be accessible, current, comprehensive, and standardized. We discuss each of these principles, the motivation for including them, and some specific examples of how they can be implemented in an IDS. We also discuss the methods used for collecting data from the field, refining, and validating the principles.

INTRODUCTION

Air Traffic Control (ATC) Specialists rely on various sources for obtaining information. In addition to the information that they receive through their primary tactical radar displays, ATC Specialists rely on other sources of information to formulate a picture of current operational conditions. These include both static data, such as documents, lists, and maps, and dynamic data, such as weather display systems or other automated tools. A well-designed Information Display System (IDS) can provide ATC Specialists with quick access to information that is typically stored piecemeal throughout a facility. In recent years, there have been several efforts to provide the Specialists with an IDS that acts as a single point of access to all of this auxiliary information.

There are several types of ATC facilities- ATC Towers, Terminal Radar Approach Controls (TRACONs), Air Route Traffic Control Centers (ARTCCs), Flight Service Stations (FSSs), and military ATC facilities. The ATC Specialists at each type of facility have different responsibilities and may have different information requirements to accomplish their tasks. At terminal facilities (Towers and TRACONs) for example, the Specialists are responsible for aircraft that are on the ground, landing, or departing. At ARTCCs, the Specialists are responsible for en route aircraft as they traverse the country before they start their final approaches into an airport.

Currently, different IDSs are used by different types of ATC facilities, or domains. The Information Display System - 4 (IDS4) and the Automated Surface Observing System (ASOS) Controller Equipment - Integrated Display System (ACE-IDS) are two systems used by terminal facilities. Flight Service facilities have limited access to these systems as well, but the systems typically contain little Flight Service-relevant information. The En Route IDS (ERIDS) is a system that was recently developed for use in ARTCCs. All of these systems currently utilize different design styles, user interaction styles, and customization capabilities. The Federal Aviation Administration (FAA) has experienced mixed success with the current systems due to design and usability issues.

An IDS is a tool that can provide access to many types of information through a single display. The design of the system is critical in determining its effectiveness. A well-designed IDS can provide the ATC Specialists with many benefits. It can be used to consolidate information to one source, allowing the user to manage large

amounts of data more easily, and can eliminate the need for multiple displays. It can also increase efficiency by providing a more logical structure and a standardized information display format (Nielsen, 2003). An IDS is also expandable, allowing for the addition of future documents and tools, and it saves money by reducing the need to produce paper documents and by increasing employee efficiency. The operational ATC environment brings with it additional design challenges in that the information required by the Specialists is often time critical and highly specialized.

The objective of this study was to investigate the IDSs currently used in different ATC domains, and to use the findings to develop a set of design principles to be applied in the development of future IDSs. We used the results of the study, together with existing design guidelines and standards, to develop design principles that are particularly important in the application of an IDS to the ATC environment. We also carried forward the lessons learned from the successes and problems of existing systems to provide a context for the principles, and to educate future system designers and evaluators.

METHOD

In developing design principles for IDSs, we adopted a multi-phased approach. First, we investigated the use of IDSs in the FSS domain. We observed the Specialists as they interacted with their current systems and conducted structured interviews with 49 Specialists to assess frequency of use, commonly used functions, system benefits, and system problems. Based on the results of the field survey and Human Factors design guidelines, we developed IDS design concepts. To illustrate and evaluate these concepts, we integrated them into a semi-interactive prototype of an IDS. We validated and refined the design concepts illustrated in the prototype with personnel from the field, and developed an initial set of IDS design principles.

Because the initial set of principles was developed after an analysis of only one AT domain, and because there are many differences in the tasks performed by different domains, the initial set of design principles had to be evaluated for extensibility. We conducted field visits to ATC facilities in the other domains. We interviewed 43 Specialists from terminal facilities and 20 Specialists from ARTCCs, and observed their use of current IDSs. We also conducted workshops with field representatives to further evaluate the applicability and comprehensiveness of the set of principles. We identified domain differences and evaluated how the principles might be applied based on the differing needs of the different user populations.

FINDINGS

Based on our findings, we proposed four general design principles for IDSs in ATC. In order to be effective, an IDS should be accessible, current, comprehensive, and standardized. Each principle represents a critical component for designing a useful and usable IDS. In the following sections, we provide a brief description of each principle, its importance in IDS design, and some examples of how it may be implemented. We also provide references to relevant sections of the Human Factors Design Standard (HF-STD-001) (Ahlstrom & Longo, 2003).

Accessible

An effective IDS makes information and tools easily accessible to the user. By accessibility, we refer to the physical accessibility to the equipment, as well as accessibility to the information contained within the system.

Physical Accessibility. The data revealed several problems with physical accessibility. Some FSS facilities only had one or two IDSs for the entire facility. This greatly limited access and reduced use of the system. Other facilities had issues surrounding the placement of the displays at the Specialists' workstations. Depending on the angle and height of the display, some Specialists reported having difficulty seeing the information. Finally, there were problems with touch panel displays (used on the ACE-IDS and ERIDS). The touch panels sometimes became misaligned causing poor touch resolution. When an alternative input device was not available, the Specialists reported becoming frustrated with having to perform repeated actions to get the system to respond.

We recommend that these issues be addressed in the selection of hardware (i.e., displays and input devices) and the placement of the displays in the workstation.

Organization of Information. Many of the systems surveyed in the field were poorly organized. When asked what they like least about their current systems, 42% of TRACON Specialists reported counterintuitive

menus, too many levels, and poor organizational structure. Forty percent of terminal controllers reported that there was too much clutter on their systems. In the ARTCCs, 30% of the Specialists interviewed reported having problems finding information due to lack of an index and poor organizational structure.

One of the most severe consequences of these issues is loss of efficiency. The Specialists in the field repeatedly stressed to us the time critical nature of the information they were accessing on their IDS. Their job tasks often require making quick decisions and providing critical information to pilots. In addition, the Specialists reported that it was extremely useful to have a single status area in the system that contained most of the operationally relevant information they need.

Another consequence of poor organizational structure is that the users did not know what information was available on their systems or how to access it. On several occasions, we found that the Specialists believed that a specific type of information was available through their IDS, but were not certain and could not specify how to find the information. In some of the systems surveyed, there was little organization of information beyond assigned page numbers, and the organization by page number was not intuitive. Some IDSs did not contain a convenient table of contents, help, or index that specialists could use to find information. They reported having difficulty finding information in the system if they could not remember the number for the page that contained the information or a page number from which to begin navigating.

Because of the potentially large amount of data warehoused on an IDS, it is critical that future systems be well organized. It is imperative that the organization of the system and its navigational structure provide quick and easy access to all of the information available on the system. To achieve this, it may be beneficial to customize the system for specific user roles (Nielsen, 2003) by providing the users with quick access to the specific types of information relevant for performing their job functions (HF-STD-001 8.1.3.9). An organization that is consistent with the user's mental model will facilitate training and make user navigation through the system more efficient (HF-STD-001, 2.3.3). In the case of ATC Specialists, our data show that the organizational structure they find to be most effective is organization by position.

In addition, we recommend having a second organizational scheme that is logical to all users, a search function, and a comprehensive index. These will make it possible for a user to quickly access any type of information available in the system (HF-STD-001, 8.16.2.16, 15.4.11), even if the information they are looking for is infrequently used.

Current

One complaint that was reported in the field was that in some systems, there was no way to determine when information was last updated. In addition, there was no easy way to add new, relevant information into the system. User acceptance and trust of an IDS depends greatly on the quality of the information it contains.

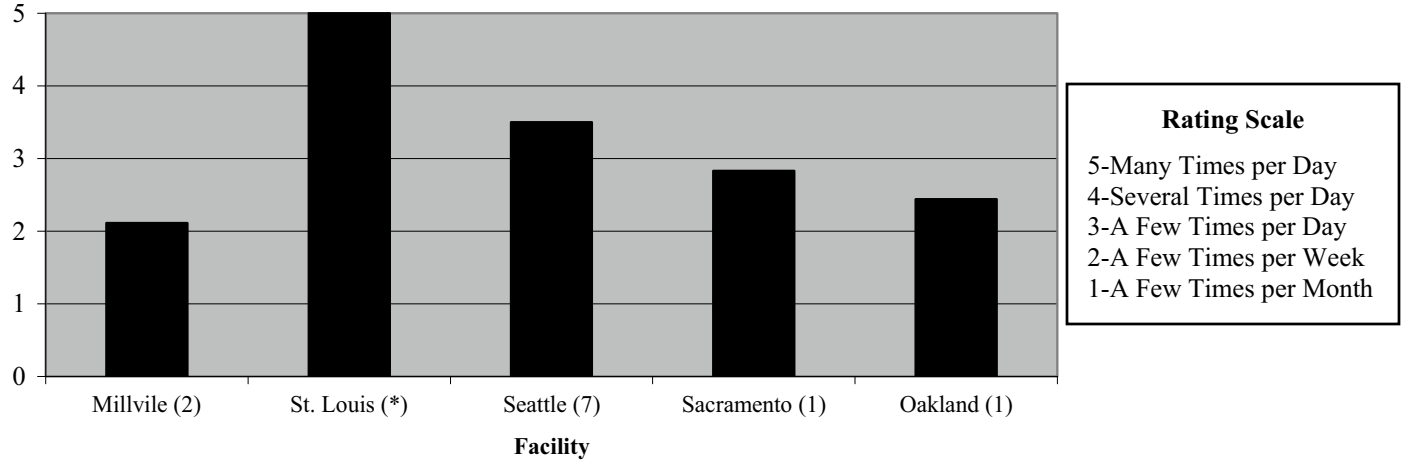

Figure 1. Ratings of IDS frequency of use with number of available displays in parentheses. (*St. Louis has IDSs at every position)

Many operational tasks rely on the user having current information. Outdated information is not only dangerous, in that it may lead to inappropriate decisions or actions by the user, it quickly causes the user to lose faith in the system and rely on it less and less (HF-STD-001 3.5.5). Therefore, IDS systems need to provide users with an indication of the currency of data.

In addition, the system should include tools that allow for easy modification of the content. When a document is updated or a new aircraft identification is created, the system administrator should be able to easily make the appropriate changes. This will ensure that the information viewed by the Specialists is complete and current.

Comprehensive

We occasionally found that the informational content of IDSs in the field was not complete or relevant for the domain in which it was being used. We found that this reduced the amount of time the Specialists spent using the system. For example, as illustrated in Figure 1, in FSSs, ratings of frequency of use increased as the number of displays increased. The Specialists found it inefficient to use the IDS for accessing some types of information while also having to rely on other sources. Many Specialists reported having to look through a lot of irrelevant information on the IDS to get to the information they needed. Others reported that their systems only contained locally relevant information, even though they often needed to access information about other facilities or areas. The lack of relevant information counteracts potential benefits of using an IDS, such as reducing printed materials, reducing the proliferation of displays, and greater efficiency in operations.

While it may seem that the greatest benefits of using an IDS may be obtained by having the maximal number of information sources all integrated into a single system, there are some types of information that should not be included. Information that requires continual monitoring, such as the tactical radar display, should not be on an IDS where it may become hidden or obscured by other information. If such information is displayed on an IDS, provisions must be made to ensure that the information is always visible.

Our data also indicate that it is not sufficient to simply make information available. The user must be able to manipulate the information in a meaningful way. For example, Specialists reported that they are not able to zoom into map images on the IDS, making it difficult to find the information they are looking for. Many of the older systems only contained scanned images that were of poor quality and did not provide any zooming capability. On some of the newer systems, the image was of better quality and the capability to zoom was available, but the image took too long to be displayed. In both instances, the information was available, but not usable.

Standardized

Standardization brings benefits such as reduced training and improved configuration management. From a usability perspective, standardization ensures that the user interface adheres to human factors design guidelines. Although some have challenged whether standardization across ATC domains is appropriate, our data indicate that there are enough commonalities in the Specialists' informational needs to warrant some level of standardization.

In the field, we observed IDS displays that were difficult to read, used too many colors, and had little or no organizational scheme. However, we also learned that different facilities do things somewhat differently and information that is useful at one facility may not be useful at another. Therefore, it is beneficial for facilities to have some control over the information displayed on their IDS. In order to provide some level of flexibility in content while preserving a standardized look and feel (DoD HCISG 14.1), we recommend that a consistent design scheme should be used throughout the system (HF-STD-001 2.3.1) while allowing each facility to customize the content and to apply an operationally meaningful organization.

DISCUSSION

The design principles described here will ensure that future IDSs provide ATC Specialists with quick access to the information and tools needed to perform their jobs. They will also ensure that future systems meet human factors guidelines as well as provide standardization throughout the different ATC domains. These principles can be applied at any phase of system development. They can be used to generate system requirements or software specification documents. They can also be used to evaluate proposed systems during vendor selection. Most importantly, these principles will educate those involved in these processes on the critical design components of an effective ATC IDS.

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