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Human Factors Assessment of the En Route Information Display System

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16. Abstract

The Federal Aviation Administration is modernizing its en route air traffic control automation system, including an En Route Information Display System (ERIDS). ERIDS provides controllers with multiple types of information electronically via a 15-inch touchscreen display at each airspace radar sector. It replaces paper documents that were shared by controllers at multiple sectors in an operations area. Researchers from the Human Factors Team – Atlantic City conducted the current study to assess the benefits of the fielded ERIDS and to identify any potential usability issues. The researchers collected questionnaire, simulation, interview, and observation data at three Air Route Traffic Control Centers using paper documents and, again, at one of the centers after ERIDS was fielded. All of the assessments of ERIDS indicate that controllers do not regularly obtain and use relatively static aeronautical information, whether it is available in paper or electronic format. The study confirmed that ERIDS eliminates the problem of paper documents not being readily available, which is the most time consuming part of the information acquisition process. With ERIDS, the information is always available at the sector position. In addition, accessing Approach Plates, which is the most frequently sought and highest rated type of information for safety and efficiency, is easy to do with ERIDS, unless the controller needs to switch between two or more plates. The researchers recommend modifications to make ERIDS easier to use and suggest that a more thorough human factors evaluation be conducted to identify and prioritize other issues and to recommend possible solutions.

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Executive Summary

The Federal Aviation Administration (FAA) is modernizing its en route air traffic control automation system, including an En Route Information Display System (ERIDS). ERIDS provides multiple types of information electronically via a 15-inch touchscreen display mounted on an articulating arm at each airspace sector radar display. ERIDS replaces paper documents that were shared between the six-to-eight sectors within an operations area. Some of the information (e.g., the Air Traffic Control Order, Standard Operating Procedures) may change only occasionally, some (e.g., sectional charts, approach plates) change at regularly scheduled intervals, and others (e.g., Notices to Airmen, Significant Meteorological information) change as events occur. The FAA estimated that ERIDS would improve controller performance by making information access faster and would reduce staff time required to maintain current data. Researchers from the Human Factors Team – Atlantic City conducted the current study to assess the benefits of the fielded ERIDS and to identify any potential human factors issues.

The researchers collected data at three Air Route Traffic Control Centers (ARTCCs) when they were using the paper documents and, again, at one of the ARTCCs after ERIDS was fielded and the controllers had sufficient time to become familiar with them (additional efforts were planned but subsequently deemed unnecessary). Ten Front Line Managers and 55 controllers participated in the data collection efforts. They completed questionnaires about the frequency of use, time and difficulty to access, and importance for safety and efficiency for nine types of information. They also performed a simulation by finding the answers to three questions each for six types of information, using either the paper or electronic format. After the questionnaires and simulation exercise, we interviewed the participants about their use of ERIDS and any problem they may have encountered with it. In addition, the researchers observed controllers as they used ERIDS in the operations areas, and interviewed staff specialists about the time and effort required to maintain both systems.

Controllers do not regularly obtain and use the relatively static information in either the paper or the electronic format, but this may vary with the characteristics of the airspace. For example, high altitude sectors need it less than low altitude sectors where controllers may be guiding an aircraft on approach to land. In those instances, ERIDS is definitely beneficial because it eliminates the problem of paper documents not being readily available, which is the most time consuming part of accessing most types of information. Approach Plates are the most frequently sought and highest rated type of information for safety and efficiency. They are easy to access in ERIDS, unless the controller needs to switch back and forth between plates. Notices to Airmen are updated more frequently in ERIDS than they were in the paper distribution system, which is beneficial, but there are several concerns (whether the controller will notice and read them in a timely manner, difficulty of reading them on the display, and a lack of cross references between navigation aids and airports that have different names) about their use in ERIDS. Several other types of information can be accessed quickly in ERIDS, especially if shortcuts are used, but the more voluminous documents (e.g., operational orders and procedures documents) are actually more difficult to use in electronic form. However, we believe there are straightforward methods to improve the usability of ERIDS with these types of documents and to address other human factors issues we identified.

Once the initial ERIDS setup (i.e., populating the databases) is completed, there are benefits in maintaining the currency of the information and in staff time to copy and distribute new information and to collect and destroy obsolete documents. The latter benefits are currently limited by the requirement to maintain backup paper documentation in the event of an ERIDS failure. Finally, the participants and some supervisors told us that ERIDS was particularly beneficial for training because the reference information was readily available.

1. INTRODUCTION

Air traffic controllers at the Federal Aviation Administration (FAA) Air Route Traffic Control Centers (ARTCCs) are responsible for maintaining the safe and efficient flow of traffic across the National Airspace System (NAS). The majority of the airspace is at high altitudes where they control aircraft during the en route phase of flight, but there is also transition airspace where aircraft climb or descend between Terminal Radar Approach Control (TRACON) and en route phases of flight. TRACON facilities use short-range radar systems to control aircraft at lower altitudes transitioning from airport tower control to ARTCCs. In some cases, usually at small airports that are not supported by a TRACON facility, the ARTCC controllers may provide services all the way to the runway. The primary responsibilities of the controllers are to maintain required separation between aircraft and to sequence the aircraft along defined routes, but they provide additional services, such as weather advisories and vectors to approaches, as time allows.

Each sector of ARTCC airspace is controlled by a radar (R-side) controller who uses processed surveillance data, flight plan data, and automation tools displayed on a radar scope, currently called the Display System Replacement (DSR), as their primary source of information and their primary tool for entering data about the aircraft (e.g., changes in altitude). The R-side controller is frequently assisted by a data (D-side) controller who observes the radar display and may use other tools (e.g., the User Request Evaluation Tool) to help plan maneuvers, enter flight plan changes, and so on. Only the R-side controller has voice communication with the aircraft pilots, but the D-side controller can assist in coordinating with Traffic Flow Management (TFM) personnel, Front Line Managers (FLMs), and controllers at adjacent sectors.

Controllers also need information from other sources to perform their tasks. Some of the information is dynamic, such as weather conditions, TFM initiatives (e.g., a required miles-in-trail restriction between aircraft to manage demand at a distant airport), airport visibility and arrival rates, activation of Special Use Airspace (SUA), which is usually a military training area that cannot be traversed by civilian aircraft when it is active, and Notices to Airmen (NOTAMs) that are issued for temporary conditions, such as navigation instrument outages. The dynamic information is usually presented on common displays in an operational area (usually six to eight sectors) or is delivered verbally or in writing by the area FLM or TFM coordinators.

Other types of information are relatively static, changing only occasionally. These types of information include definitions and procedures in the Air Traffic Control (ATC) operations order (FAA Order 7110.65); aeronautical charts; Approach Plates (i.e., required routes of flight into and out of airports when under instrument flight rules); Aeronautical Information Manual (AIM); Location Identifiers (FAA Order 7350.7); Contractions (FAA Order 7340.1); facility orders; training manuals; and so on. Until recently, the static types of information were normally available as written documents in the operations area; some of the documents can be voluminous. The Facility Operations and Administration (FAA Order 7210.3) defines the types of information that must be available in the information binder located in the operations area, but each sector is individually developed by the facility air traffic manager.

These methods of information delivery had some inherent inefficiencies because the information was not readily accessible to controllers at their positions. For example, one of the sector controllers may have had to leave his or her position to access information (manuals, facility information, charts, etc.) to respond to a pilot’s request, and another controller may have been using it or had not returned it to its normal location. In other cases, there might have been a significant lag between when the information was generated and when it was received by the controllers. For example, NOTAMs were normally distributed to the facility on an hourly basis and then further redistributed to the controllers, with an additional delay of up to 10-15 minutes.

The FAA is developing an En Route Automation Modernization (ERAM) system that includes an En Route Information Display System (ERIDS). ERIDS is part of the FAA plan to provide information in electronic format to air traffic controllers, FLMs, and TFM personnel. ERIDS was initially deployed as a prototype to three ARTCCs. The FAA (2003) estimated that ERIDS would improve controller performance in terms of safety and efficiency by making information accessible to the controllers faster. The FAA also estimates that the electronic system would save substantial staff time in processing the information. The FAA obtained data to support those estimates from telephone surveys with one representative at each of the prototype ARTCC facilities and representatives from the National Air Traffic Controllers Association, the Air Traffic DSR Evolution Team, and the FAA Requirements organization. To further evaluate the benefits of ERIDS, Jha and Sollenberger (2005a) conducted a cognitive walkthrough with en route controller Subject Matter Experts (SMEs) to identify their information needs that were not provided on their radar displays. Those data were then used to perform an analytic assessment of ERIDS (Jha & Sollenberger, 2005b). Subsequently, Sollenberger, Koros, and Hale (2008) collected data about how controllers accessed information without ERIDS and with a prototype ERIDS.

1.1 Air Traffic Controller Non-DSI Information Needs Analysis

Rodgers and Dreschsler published a Job-Task Analysis (JTA) of en route controllers in 1993 based on analyses that had been performed in the 1980s. The JTA identified nine categories of information that controllers need to perform their jobs: traffic management, SUA, emergency or contingency, weather, equipment, airspace and aeronautical, operating policies and procedures, airspace intrusions, and security information. Because information requirements and delivery procedures may have changed since those analyses were performed, Jha and Sollenberger (2005a) conducted a cognitive walkthrough with air traffic controllers to ensure that the data about current needs and procedures were accurate. A cognitive walkthrough is a process in which SMEs think through the steps in their job performance in a systematic procedure.

The detailed purpose of the cognitive walkthrough was (a) to identify en route controller dynamic and static information needs that are not available on the DSR; (b) to create a baseline for how controllers accessed information in the system prior to ERIDS by estimating task times, update rates, and frequency-of-use rates; and (c) to identify sources of information and their criticality for ATC safety and efficiency.

Three current supervisory controllers and three retired air traffic controllers participated as SMEs in the cognitive walkthrough. Researchers from the Human Factors Research and Engineering Group (HFREG) Team - Atlantic City conducted the 2-day activity at the FAA William J. Hughes Technical Center (WJHTC) Research, Development, and Human Factors Laboratory. First, the researchers outlined the objectives of the project and presented an overview of ERIDS to the SMEs. Then they gave the SMEs binders containing a written introduction about the study, a briefing on ERIDS, and a questionnaire. The questionnaire consisted of the nine ATC information categories adapted from Rodgers and Dreschsler (1993) and a list of questions designed to identify information items, the format of the information, how the information is normally obtained, and the relevance of the information to controller performance.

The researchers conducted the cognitive walkthrough by electronically presenting the questionnaire on a large projection screen and asking the SMEs to address the questions. They entered SME comments into the display system so that they could be shown to everyone to aid the discussion. If any important information was missed during the session, the researchers encouraged the SMEs to record it on the paper questionnaires.

Jha and Sollenberger (2005a) reported that the SMEs identified 10 categories of ATC information that controllers often need to perform their job (see Figure 1). Of the initial nine information categories from the JTA, the SMEs believed that Airspace Intrusions and Security Information categories were part of Special Operations and, therefore, the SMEs combined them into a single category. Two new categories emerged during the walkthrough: Aircraft Data (e.g., number and type of engines; rate of climb) and Miscellaneous (mostly administrative items such as the work schedule, training requirements, and airline contact information). The following subsections describe each category in more detail.

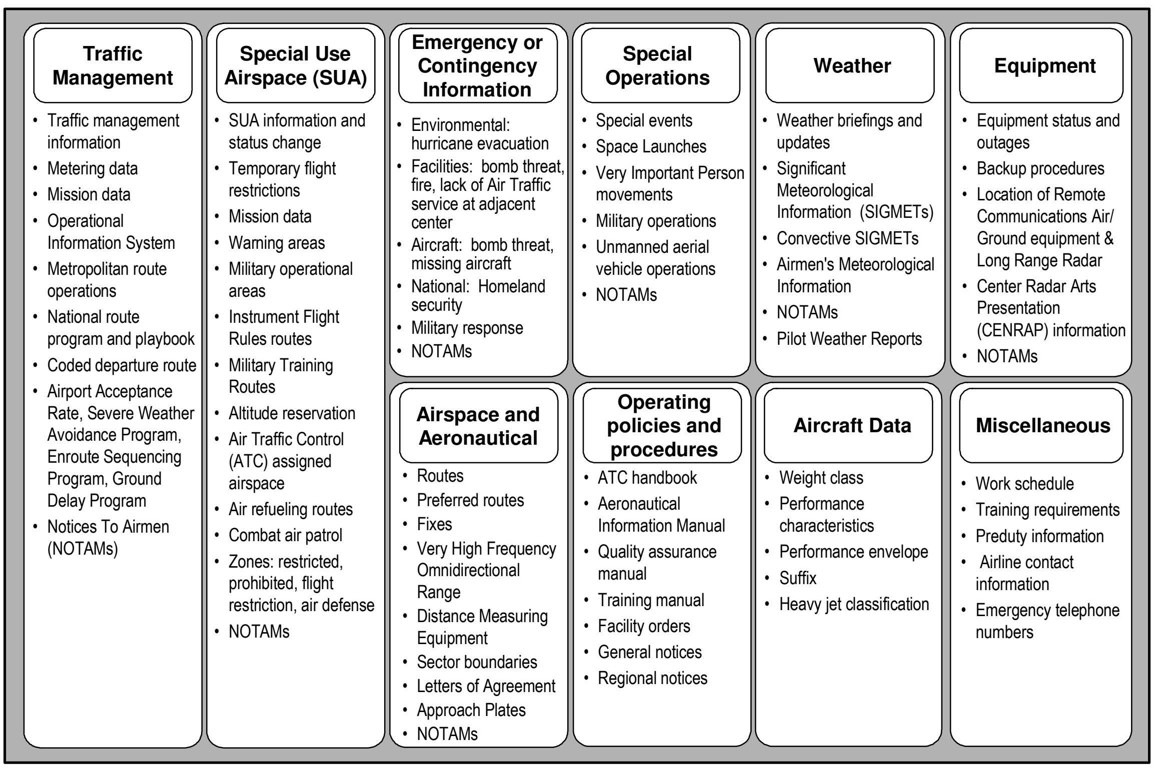

Figure 1. En route air traffic controller information requirements.

1.1.1 Traffic Management Information

TFM information can be generated nationally by the Air Traffic Control System Command Center (see http://www.fly.faa.gov/Products/products.jsp) or by the TFM unit at an ARTCC. There are 20 ARTCCs in the conterminous U.S. airspace. Traffic management initiatives are designed to maintain a smooth flow of aircraft so that demand on an airport or a volume of airspace does not exceed capacity, which would necessitate airborne holding. They are also designed to ensure that the number of aircraft being controlled by individual sectors does not exceed the capabilities of the controllers to maintain separation of the aircraft. The initiatives can include metering aircraft to a geographic fix, maintaining minimum miles between aircraft on a route so that two or more streams of traffic can merge at a fix, ground delay programs, ground stop programs, departure spacing programs, airspace flow programs, and severe weather avoidance programs. Weather conditions, scheduled flights, sector loadings, and airport arrival rates drive the decisions for managing the traffic.

Traffic management information is dynamic and subject to change at any time, although some elements of it are preplanned (e.g., national and local playbooks, which contain preferred routing options). Much of the information is displayed on large screens or monitors located in the operations area. The FLM controls the information displayed by the Enhanced Status Information System (ESIS), so that it contains only information that is relevant to the sectors in the area. FLMs can also provide other traffic management information verbally or written on paper strips. TFM information can be included in position relief briefings when the controller working a sector goes on break or to attend to other duties. Finally, binders in the area contain the preplanned traffic management information.

When TFM initiatives are in effect, they are critical to maintaining system efficiency and can be critical to safety (e.g., avoiding severe weather). Because most TFM information can change frequently, it needs to be readily available, and ESIS provides this capability. Depending on the amount of information being displayed, it requires only a few seconds to read. Information conveyed by the FLM also takes only a few seconds. The SMEs estimated that it takes only about 1 minute to find and read information in binders once they are located, but normally the D-side controller or FLM will locate the binder for the R-side controller. Although some of the static information may be remembered if used frequently, there is no requirement for the controllers to memorize it.

1.1.2 Special Use Airspace

SUA is airspace that contains limitations on who can use it, if at all, either permanently or temporarily. The most common SUAs are military operations areas, which when active can only be used by military aircraft. There are also military training routes and military altitude reservations for refueling that may or may not be active. There are certain locations where there are permanent restrictions on use or which are prohibited for all civil aircraft. These can include government facilities, nuclear power plants, and even the homes of former presidents. They are marked on aeronautical charts and are memorized by the controllers. Other airspace may be restricted or prohibited on a temporary basis, such as during major professional sporting events or a location where the president or vice president is visiting. Having knowledge of SUA and the required procedures associated with its use are critical to safety and can affect efficiency by providing access to more direct routes when it is not active.

Some SUA location information is depicted on the DSR or aeronautical charts located at the sector. SUA activation is normally displayed on the ESIS. Both are continuously available to the controllers and take only a few seconds to read each item. Additional SUA information may be available in written form, such as military briefing packets, NOTAMs, and binders. Controllers normally review them before taking over a position, which generally takes 1 to 10 minutes. FLMs can transmit SUA information verbally, and controllers share this information during the position relief briefing. SUA information that is available on charts is updated on a regular schedule (28 or 56 days); other information is updated as needed.

1.1.3 Emergency or Contingency Information

This type of information is primarily procedures to be followed in the event of an emergency. The information is available in binders in the area. The information can be related to environmental events (e.g., hurricanes, tornadoes, earthquakes), facility events (e.g., loss of air traffic systems such as radar or communications), aircraft events (e.g., missing aircraft, bomb or hijack threat, engine or equipment failure, passenger medical emergency), national events (e.g., terrorist threat), and military responses (e.g., intercept of aircraft intruding into restricted airspace). Notification of the event can be received from the FLM, air-ground radio (aircraft emergency), or telephone (e.g., from maintenance, if there is a problem affecting only one sector). Aircraft emergencies occur relatively frequently, most environmental events are relatively rare and seasonal; the other events are rare.

The procedures for addressing these events do not change very often, perhaps not for years. The controllers should be aware of the procedures but are not required to memorize all of them, especially the more rare events, so they may need to access the procedural information when events occur. The length of time to access the information varies, depending on how long it takes to physically locate the binder, and then on how long it takes to locate and read the specific information. The SMEs estimated that the process could take from a few seconds to 10 minutes. Obtaining the information is critical to safety and can have an impact on efficiency (e.g., recovering from a system failure).

1.1.4 Special Operations Information

Facility specialists prepare special operations information for specific events, such as major sports events, space launches, travel by very important persons (e.g., the president, vice president, and visiting heads of state), large scale military operations, and flights by unmanned aerial systems. They provide full packets of maps and operational details to controllers working the affected sectors. The controllers review the materials before assuming responsibility for the sector and can review the packages on position, if needed. They can discuss the information with the FLM prior to assuming the position and while working the sector (e.g., any time the president’s airplane is in the sector, the FLM must monitor the operation). The time required to review the materials depends on the complexity of the operation. The ESIS display may indicate the operation is in progress, but it will not display the details. The information is critical to perform the operation safely and efficiently.

1.1.5 Weather Information

Whenever the weather is not clear, the en route controllers need to know what the conditions are currently and what they are projected to be in the near future. This information, especially when the weather conditions are severely adverse, is critical for maintaining the safety of the aircraft and for the efficient use of the airspace. The controllers obtain this dynamic information from multiple sources, but in different ways. Precipitation data in and near the sector can be displayed on the radar scope at three levels of intensity; however, the update rate for the displayed precipitation can be several minutes, so a fast-moving storm could move several miles between updates. In addition, there are only four display options for selecting altitude strata, so indicated precipitation could actually be located below the sectors' airspace limit. ESIS can display National Weather Service satellite and radar graphics so that the controllers can discern larger scale weather movements. ARTCC meteorologists produce and distribute weather briefings, which include forecast conditions. Notices of relevant weather conditions are regularly updated in written strips; these include NOTAMs, Airmen's Meteorological (AIRMET) information, Significant Meteorological (SIGMET) information, convective SIGMET, and pilot weather reports (PIREPS) that are distributed either to affected sectors or directly from a pilot. These written notices may incur several minutes of delay from receipt at the facility until they are distributed to the controllers.

1.1.6 Equipment Information

The most important equipment information is the status of the multiple systems (e.g., surveillance, navigation, communication, and automation) used by air traffic controllers, especially if there are outages that may affect the operations. In those instances, the information is critical to safety and efficiency. Status information can be displayed (a) on the ESIS system; (b) in General Information (GI) messages displayed on strips; (c) in NOTAMs, if the outage will last long enough to warrant notifying airmen; and (d) verbally from the FLM. Controllers also need to know the location of equipment (e.g., radars, remote communication air-to-ground transceivers) and backup procedures when equipment fails. Most of the equipment information is readily available when needed by the controllers.

1.1.7 Airspace and Aeronautical Information

There are multiple types of airspace and aeronautical information that are critical for safety and efficiency. Controllers must know the sector boundaries, location of navigation aids (NAVAIDs), published routes, preferred routes, and fixes (named locations) along routes to be certified on a sector. They must also be knowledgeable of Letters of Agreement (LOAs) between facilities. Commonly used approaches are also memorized. However, controllers access rarely used or highly detailed sector information, elements of agreements, or approaches as needed. This information is available on overhead charts, in binders, or in packets of Approach Plates. As changes occur within the sector (e.g., new routes added), the charts and Approach Plates are updated on scheduled cycles of 28 or 56 days. Changes to LOAs are made as needed. If the R-side controller needs information that is not readily available (e.g., on an overhead chart), typically the D-side controller or FLM will obtain the information. This process may take from a few seconds to several minutes (the SMEs estimated as much as 5 minutes) to obtain the required information.

1.1.8 Operating Policies and Procedures Information

The operating policies and procedures include the ATC Order, AIM, Quality Assurance Manual, Training Manual, Facility Orders, and Standard Operating Procedures (SOPs). Most of this information is memorized, but it is available in written form to reference for clarification or details. It is only updated, as required, when there are changes to procedures or policies. General notices (GENOTs) and Regional notices (RENOTs) may be sent to the facility by fax and then distributed by FLMs. This information is used continuously and is critical for safety and efficiency.

1.1.9 Aircraft Data

Aircraft data describe the characteristics of all aircraft that fly in the NAS. The aircraft data include weight class, number and type of engines, flight plan suffixes, and performance characteristics (e.g., climb and descent rates, land and hold short distance minima). These data are available as appendixes in the ATC Order. Controllers only need to access the information for aircraft that do not regularly fly in the sector; they maintain familiarity with the characteristics of regular aircraft in their sector.

1.1.10 Miscellaneous Information

This category mostly refers to administrative information, such as work schedules, break times, training requirements, and preduty information. It also includes emergency telephone numbers and airline contact information. It is available in written form within the operations area, either at the FLM desk or near the controller sign in/sign out area. It is normally accessed when the controllers are not working on position.

1.1.11 Summary of the Cognitive Walkthrough Results

In addition to the operational information presented on the DSR and related automation systems, en route air traffic controllers require numerous types of dynamic and static information to perform their jobs. Most of the dynamic information is readily available (e.g., on ESIS), but some can be delayed in reaching the controller (e.g., NOTAMs). Some of the relatively static information is available at the sector (e.g., overhead chart), but most of it is available as written materials within the operations area, and either the D-side or FLM has to locate the information and provide it to the R-side controller. This process may take several minutes, especially if the folder or binder is not in its normal location. For some of the more voluminous documents (e.g., the ATC Order and AIM), it may take considerable time to locate the specific information needed. Faster and easier access to the required information should facilitate the performance of the controller.

1.2 ERIDS Description

This description of ERIDS is based on reviews of documentation (System/Subsystem Design Description, Operational ERIDS Course Overview for Boston ARTCC, and screen shots of ERIDS); on observations and discussions with staff during field visits to two prototype ERIDS ARTCCs and a visit to one fielded ERIDS ARTCC; and on exercising the ERIDS used for test and evaluation at the WJHTC.

The type of ERIDS display is dependent on the position (controller, FLM, or administrator), but this description focuses on the controller system. Each controller has a 15″ touchscreen at the sector workstation. Controllers can enter data or request information using a touchscreen display with an electronic keyboard that can be operated either by their fingertips or a stylus. The touchscreen is mounted on an articulating arm on the upper side of the DSR workstation console and is accessible from the R-side and the D-side controller positions (see Figure 2; the ERIDS display is on the left and right of two adjacent radar positions). The articulating arm enables a controller to pull the display close to them for use and to push it out of the way when finished.

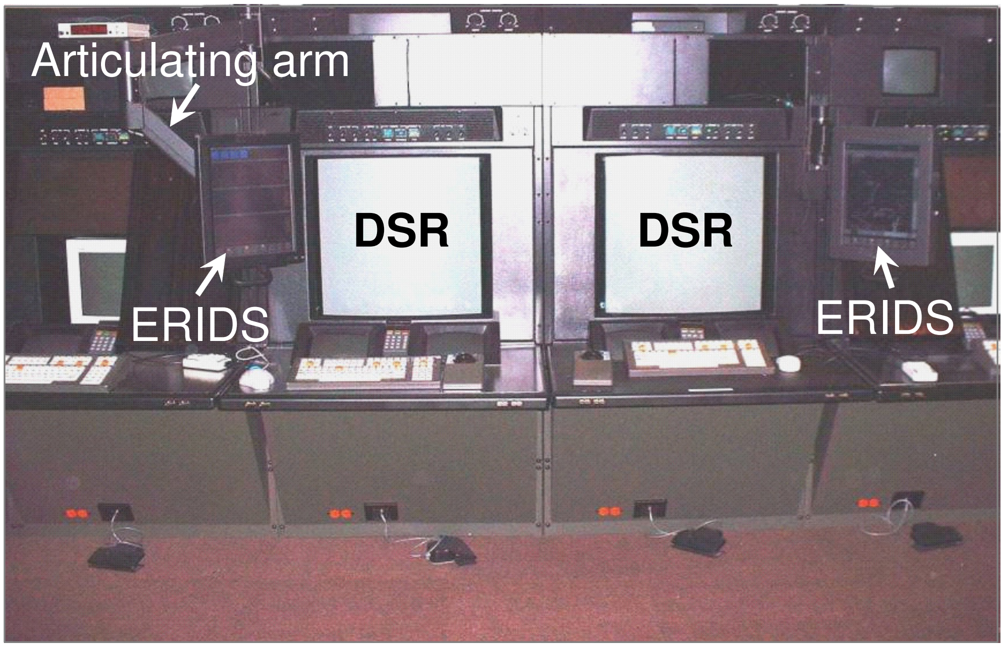

Figure 2. En Route Information Displays at the controller positions.

ERIDS operates on a Sun Solaris platform, and its front end uses browser-based technology that was developed using Internet Explorer. A database stores all of the information. All maps, charts, and documents are in Portable Document Format (PDF) files.

1.2.1 ERIDS Interface

Most of the monitor area displays information or submenu buttons, but there are two rows of buttons always available that the controller uses to interact with the system (see Figure 3). The gray buttons are standard across all systems. The Home page button is at the lower left and displays NOTAMs messages (see Figure 3). Having NOTAMs messages as the Home page should allow the controller to skim any relevant notices at a glance. The number of unread messages is displayed on the Messages button to alert the controllers of pending messages.

The Messages button opens a submenu that allows the controller to select message type (alerts, notices of combining or decombining sectors, equipment outages, GI messages, military airspace, or NOTAMs), which can then be selected and read. Pressing the Messages button also allows the controller to create and send messages. Pressing the Weather button only enables the controller to create and distribute a PIREP but may in the future be tied into other weather information. At the time of this study, the Interim Air Traffic Procedures for ERIDS (FAA Notice N JO 7210.653) specifically precluded the presentation of other weather information via ERIDS.

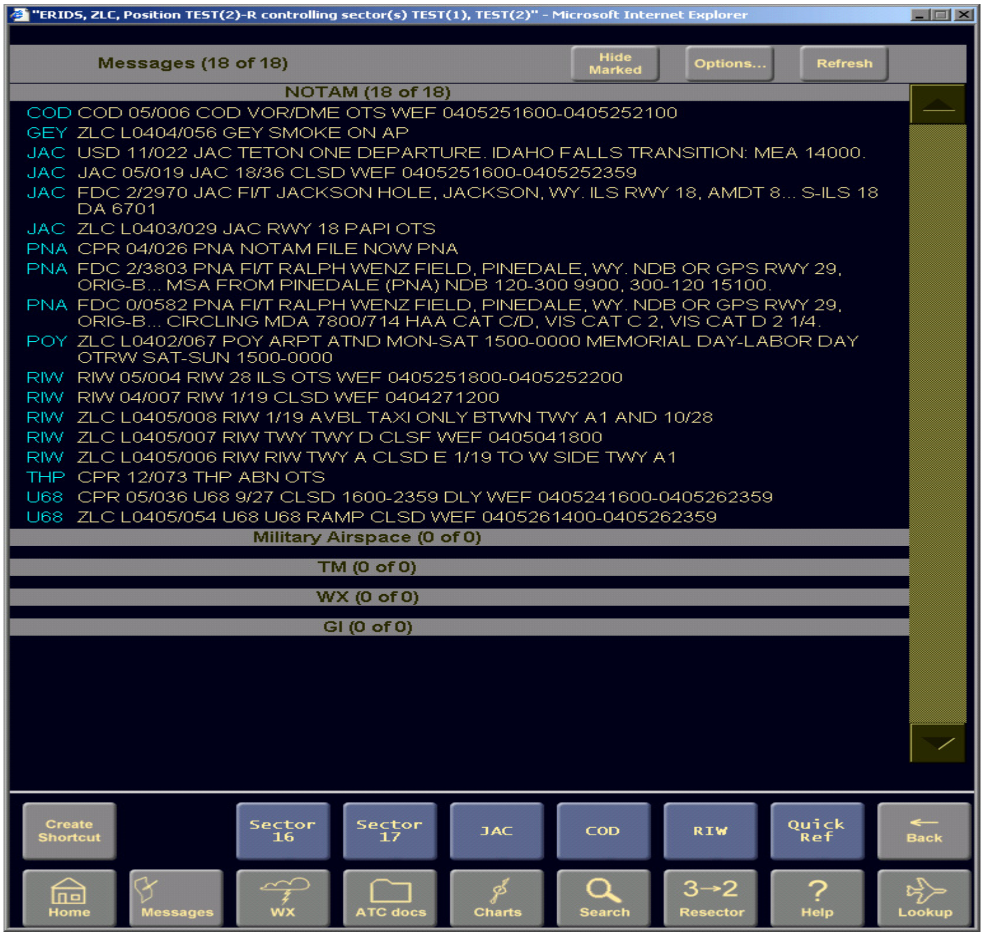

Figure 3. The Home page of the En Route Information Display System.

Controllers can access various types of static information through multiple methods. The ATC Docs button opens a submenu where the controller can open both national and local text documents. There is a core set of documents (e.g., the ATC Order, Location Identifiers, Contractions, Facility Operations, AIM, SOPs, and LOAs), but all documents can be accessed by selecting a submenu. The Charts button opens a submenu allowing the controller to select various types of graphical and textual information; for example, overhead charts, sectional maps, Approach Plates, Standard Instrument Departure (SID) routes, Standard Terminal Arrival Routes (STARs), and airport diagrams.

In addition to locating information in the ATC documents and charts, controllers can use the Search and Lookup buttons. These options require the controller to enter text (e.g., a fix name or an airport approach type) via a soft keyboard to find the information needed. Depending on the page, there may be additional buttons or links to find the needed information.

The Resector button is used for the initial log-on and to modify the sector assignment (e.g., combine or decombine sectors depending on traffic volume). The Help button provides information about ERIDS, the information that is available in it, and instructions for navigating in the system. On the right end of the upper row, the Back button steps the controller back through previously selected pages. The controller can always select another button and go directly to another information source. The Quick Reference button leads to documents that are used relatively frequently but not often enough to be a first level button. On the left end of the upper row is a button used to create shortcuts for the specific sector. The remaining buttons (shown in Figure 3) provide quick access to information about Sectors 16 and 17 (these are the sector binders containing required information per FAA Orders N JO 7210.653 and 7210.3) and to information about airports at Jackson Hole, Cody, and Riverton, WY (these can be created by the controller working the position).

1.2.2 ERIDS Update Rate

The updates to national information and documentation are sent to facilities electronically on a regularly scheduled basis. A central publishing laboratory compiles and processes the data into an ERIDS-compatible format. Each facility verifies the data and then loads it into the system. Any information that is originated for local use can be updated in the system on an as needed basis. ERIDS automatically retrieves and distributes NOTAMs from the NOTAM distribution system at periodic intervals. Other relevant messages, such as GI messages, are transmitted as needed.

1.3 Human Factors Analytical Assessment of ERIDS

Jha and Sollenberger (2005b) conducted an analytical human factors assessment of the prototype ERIDS to provide the information needed by en route controllers in comparison to the predecessor system of paper or verbal transmission of information. They based their assessment on a review of available ERIDS documentation, a field visit to ARTCCs with prototype ERIDS, comments from the SMEs during the cognitive walkthrough, and the researchers' knowledge of human factors guidelines and standards. They assessed dynamic and static information separately.

1.3.1 Dynamic Information

Much of the dynamic information is presented on the ESIS display and, therefore, will be unaffected by the introduction of ERIDS. In fact, FAA Order N JO 7210.63 specifically excludes the distribution of many types of dynamic information (e.g., MIT restrictions, runway in use, and weather information) through ERIDS. The primary use of ERIDS for dynamic information will be the distribution of messages, especially NOTAMs. Before ERIDS, Flight Data Specialists polled the Aeronautical Information System – Replacement (AIS-R) periodically for relevant NOTAMs. They then printed and distributed the NOTAMs to the FLMs at the affected operations areas who would then deliver the messages to controllers at their positions. The SMEs in the cognitive walkthrough estimated that there can be 10-15 minutes delay in distributing NOTAMs from the time they are received at the facility. Distribution of messages to the relevant controller positions in ERIDS should be much faster. However, whether controllers will access and read this information earlier with ERIDS cannot be assured because the system increases the number of tasks that controllers perform to get the information. Instead of just receiving and reviewing an incoming message, the controller must monitor and notice that a new message has been received, pull the ERIDS display so that it can be read, navigate to the Messages page and find the relevant information (unless it is a NOTAM, where it will appear on the Home page), read the information, return to the Home page, and stow the display.

Especially during high workload operations, controllers may be focused on controlling traffic and may not notice or review incoming information until a later time. ERIDS provides a visual alert displaying the number of unread messages in the Messages button. However, the visual cue conveys no information about the importance of the message. If the display is in a stowed position, away from the controller, the visual alert may not be conspicuous and may not be readable without pulling the display closer. ERIDS does not have an audio alarm that alerts controllers about a new incoming message. The authors confirmed the issue of reduced awareness during an informal conversation with controllers at an ARTCC where they were using the prototype ERIDS.

Therefore, Jha and Sollenberger (2005b) could not make a direct, positive link between making dynamic information available faster using ERIDS and controller performance in terms of safety and efficiency. Although ERIDS may provide the most current information, controllers are not required to have the most current NOTAM information. In certain cases, ERIDS may be able to provide information that may affect efficiency. For example, information on the availability of SUA may help a controller manage traffic better.

1.3.2 Static Information

Most of the required static information will be available in ERIDS, or at least could be. For example, it is not clear whether special operations information and miscellaneous information (especially parts that change relatively frequently) will be entered into the database. As in the case with dynamic information, ERIDS will increase the number of tasks performed by sector controllers to obtain static information. The SMEs' comments during the cognitive walkthrough suggest that controllers normally request information from either an FLM or a D-side controller when needed. Then either the D-side controller or the FLM will find the requested information and provide it to the controller. With ERIDS, the R-side controller performs the search, unless a D-side controller is assigned to the sector. Nonetheless, finding paper documents likely requires the most time in the total task of finding information, so having electronic data available at the position may reduce the total task time, assuming the ERIDS databases are well organized, data entry is easy to do, and the search capabilities function well.

Electronic media is faster and has advantages for certain tasks, such as searching for information; however, it is not best for other tasks, such as reading (O'Hara & Sellen, 1997). Reading in an electronic format can be slower compared to reading in a paper format, depending on image quality, font size, and contrast between the text or graphic and the background. Unless the information is short (i.e., less than one page on the display), the controller (a) must scroll through the document, (b) will likely be uncertain of the location within the document or know how much material remains to be read, and (c) will probably be unable to make annotations to the data.

Jha and Sollenberger (2005b) could not ascertain a direct relationship between the availability of static information in ERIDS with controller performance (safety and efficiency). ERIDS will provide the information at the position, so it may relieve the area FLM of retrieving and delivering information to controllers and allows them to concentrate on traffic management in their area. At the same time, it may increase the tasks required of the R-side controller, even if the information can be acquired in less total time. The benefits of ERIDS may also be contingent on the sector position. For example, ERIDS may be more beneficial for low altitude sectors than for high altitude sectors. Controllers in low altitude sectors frequently need to access information, such as Approach Plates, which should be relatively easy to access in ERIDS, especially if short cuts are used.

1.3.3 Usability Issues Observed

During the course of the benefits assessment, Jha and Sollenberger (2005b) identified four usability issues with the prototype ERIDS. ERIDS has a capability to display charts and maps; however, because of the limited screen size, controllers must pan, zoom, and recenter to view a specific area and can lose the perspective view, which makes using these maps difficult. Because of the graphical nature of maps and charts, the large files can take a long time to upload and display in ERIDS. Second, ERIDS does not provide any auditory alerts or alarms that convey the presence of an incoming status message or the urgency of the message to controllers. In some configurations, ERIDS may be mounted on one side of the R-side position and, therefore, may not be readily accessible to the D-side controller without interfering with the R-side. Finally, the touch entry can be slow, and there is a lack of feedback to the user that the input was accepted.

1.4 Prototype ERIDS Benefits Study

Because the analytical assessment could not clearly identify positive benefits of using ERIDS in terms of controller performance, Jha and Sollenberger (2005b) recommended that the FAA conduct a field study to collect empirical data about the use of ERIDS. Subsequently, Sollenberger et al. (2008) spent 3 days each at two ARTCCs, one of which had been using an ERIDS prototype; the other ARTCC was still using the manual information system. They collected five types of data while at each center. First, they observed controllers in the operations areas and noted how frequently they accessed information and how long it took to complete the task. Second, 37 FLMs and TFM coordinators (17 were experienced with using ERIDS) participated in a simulated exercise in which they had to find seven types of information (three questions for each type) using paper sources or ERIDS. The seven types of information were from the ATC Order, Location Identifiers manual, Contractions manual, AIM, Approach Plates, SOPs, and LOAs. They used a laptop computer to present each question and to measure how long it took to find the information. At the ERIDS ARTCC, the participants used an ERIDS located away from the operations area; at both ARTCCs, all the required paper documents were readily available.

Third, the participants completed ratings for nine types of information on how frequently they accessed each one, how long it took to obtain the information, how difficult it was to access, and how important the information was for safety and again for efficiency. The nine types included the same sources as in the simulation plus Special Military Operations Manual (FAA Order 7210.4) and the Facility Operations & Administration Manual (FAA Order 7210.3). The ERIDS users were also asked to rate whether and by how much the electronic system had decreased or increased their workload. Fourth, they obtained data from ERIDS to determine which types of information were accessed most often by controllers across the center for a 1-year period. Finally, they interviewed staff personnel who were responsible for establishing and maintaining the information systems to determine the level of effort required in each.

Sollenberger et al. (2008) observed that R-side controllers rarely used manuals or ERIDS to obtain information while working live operations. The participants told the researchers that controllers normally ask the FLM or D-side controller (if they were not too busy) to obtain information for them. The participants also commented that the reference manuals are difficult to find when they are not in their assigned location. The researchers attempted to locate the different manuals in one of the centers. Although some areas were neatly organized, other areas did not have all the required manuals available, Approach Plate booklets were scattered in multiple locations, and some pages were damaged or missing. The participants indicated that finding the reference manuals could take several minutes.

In the simulation exercise, the differences between the paper manual and ERIDS methods in time to access was generally small, especially considering the high degree of variability across participants. Certainly, the additional time to find paper manuals if they were not immediately available would greatly exceed any differences with ERIDS. The average time to access information per question ranged from 18.5 s to 172.6 s for paper manuals and from 13.7 s to 148.2 s for ERIDS. The respective standard deviations (*SDs*) ranged from 4.88 s to 136.25 s for paper manuals and from 3.89 s to 111.99 s for ERIDS. Within the ERIDS facility, using the ERIDS was slightly slower than paper manuals except for Location Identifiers and Contractions. The researchers noted that the ERIDS interface is well designed to search in these two documents. In both methods, the participants took the longest time to find information in the ATC Order and in AIM, both of which are voluminous. The researchers pointed out that, unlike the paper manual, there is no index of keywords in ERIDS so the participants had to identify the relevant chapter in the table of contents, which seemed to be a slower method of searching.

On the questionnaires, the participants indicated that when using paper references, they rarely accessed most types of information during a shift except for Approach Plates. There was large variability in the participant's responses on how frequently they accessed the Approach Plates, probably indicating differences in the airspace and airports between operations areas. Within the ERIDS ARTCC the participants estimated that more information would be accessed with electronic data, especially for Location Identifiers and Contractions. Participants at both centers estimated the time to access information with paper reference materials would be much longer (averages ranged from 2.2 min to 7.5 min) than found in the simulation exercise, reflecting the time required to locate the relevant document. Using ERIDS, they estimated substantially shorter times (averages ranging from 0.6 min to 2.4 min). They estimated the shortest times for Location Identifiers, Contractions, and Approach Plates, which generally corresponded with the simulation data. Their average estimate of the time to locate LOAs was substantially longer than the simulation times (2.3 min vs. 37.2 s).

Using a rating scale that ranged from 1 (*not difficult*) to 10 (*very difficult*), the participants rated accessing information using paper references as *moderately difficult* (4.9 to 6.8). According to the participants, finding information in Approach Plates was the least difficult and finding information in the AIM was the most difficult. They rated ERIDS as much lower in difficulty (ranging from 2.2 to 3.8) for all types of information. The ATC Order was the most difficult to access using ERIDS. Using a scale that ranged from 1 (*decreases workload a great deal*) to 10 (*increases workload a great deal*), the ERIDS ARTCC participants indicated that ERIDS *decreased* their workload compared to paper manuals (average ratings of 1.9 to 3.7). Location Identifiers were rated as *decreasing workload the most* and the Facility Operations &

Administration Manual as *decreasing workload the least*. Finally, using a scale that ranged from 1 (*not critical*) to 10 (*very critical*), the participants rated the nine types of information from *moderately to highly critical* for both safety and efficiency. The lowest ratings were 2.9 for safety and 5.5 for efficiency for the Facility Operations and Administration Manual; the highest ratings were 9.4 for safety and 9.1 for efficiency for Approach Plates.

The quarterly report data showed that LOAs, Approach Plates, and SOPs were the most frequently accessed information across the center for the preceding year. On average, they were accessed 58.6, 47.3, and 43.5 times per day, respectively. The next three types (and daily means) of information accessed were the ATC Order (M = 17.6), Location Identifiers (M = 16.5), and Contractions (M = 7.3). The researchers noted that there were missing data in some quarters and that the Location Identifiers can also be accessed using the Facility Lookup function, so these may be underreported. Considering the ERIDS ARTCC had five operational areas with approximately six radar sectors each, operating essentially 24 hours each day (some sectors are combined at night when the traffic volume is low), this result confirms the participant ratings and area observations that controllers do not frequently need information of these types. However, their estimates of frequency of accessing the information does not correspond well with the actual usage (Location Identifiers and Contractions were rated as being accessed almost as often as Approach Plates, and access to LOAs and SOPs was estimated much lower).

Sollenberger et al. (2008) reported that three Airspace and Procedures Specialists at the non-ERIDS center maintain local documents. The most time-consuming tasks are editing the documents for accuracy, and then printing and copying them for dissemination to all the operational, Traffic Management, and Operations Management areas of the center. Part of the dissemination process is to collect and discard the old paper documents. In addition, an Administrative Assistant and a mail clerk process national documents. At the ERIDS center, three Specialists maintain the local documents, and an ERIDS Specialist maintains the national documents by uploading digital information every 112 days. Overall, Sollenberger et al. estimated that it required 74 staff hours per month to maintain the paper system and 58 hours to maintain the ERIDS data. They were told that the initial setup of ERIDS was very labor intensive and required 3 months of effort from four Specialists to scan all the local documents and build the links within ERIDS, but that was a one-time effort.

Sollenberger et al. (2008) concluded that although controllers do not need non-DSR static information very often, they can access it, if needed, faster with ERIDS than with paper documents, unless the document is available at the workstation. With documents readily available, finding the desired information can be slightly faster or slower with ERIDS, depending on the search capabilities. Finding information about Approach Plates, Location Identifiers, and Contractions is relatively easy with ERIDS; however, finding information in the ATC Order or AIM is not. Once ERIDS is initially set up, it requires less staff hours to maintain the databases.

1.5 Fielded ERIDS Assessment

There were several limitations to the Sollenberger et al. (2008) benefits study. First, they conducted the evaluation using the prototype system rather than the fielded system that evolved from it. Second, comparisons between the paper-only facility participants timing data with the ERIDS facility participants could have been affected by differences in the information they were asked to access. Although the types of questions were the same, most of the questions were facility-specific (e.g., Location Identifiers and Approach Plates were within the facility area of responsibility). Third, the participants at the ERIDS facility had not been using the paper documents for some time, so the comparison of time to acquire information may have been affected. For some types of information, however, they were as fast as or faster than the paper-only participants. Finally, all of the participants in the simulation and questionnaire rating components of the data collection effort were FLMs or TFM personnel, not controllers who are the primary users of ERIDS.

As a result, researchers from the Human Factors Team – Atlantic City planned a human factors assessment for the fielded system. The Human Factors Research and Engineering Group in the Air Traffic Organization – Operations Planning (ATO-P) organization of the FAA sponsored the project at the request of the ERAM program office in the En Route and Oceanic Services organization (ATO-E). The plan was similar to the Sollenberger et al. (2008) procedure, except that paper data would be collected at three ARTCCs (two of which were scheduled to be the first to receive the fielded system, and the other had special airspace characteristics) before they received ERIDS, and then ERIDS data would be collected at the first two facilities after they received the ERIDS and had sufficient time to become proficient in its use. Because of delays in fielding the system and collecting the post-implementation data, and because the results from the first facility were deemed sufficient, the researchers and sponsors decided not to conduct the second ERIDS data collection.

2. METHOD

All four questionnaire and simulation data collection efforts were identical, except that we used only paper documents in the first three and only ERIDS in the last one. The researchers conducted staff interviews about setting up and maintaining ERIDS in comparison to the paper system and observed area operations only in the final data collection. Three researchers participated in each of the 3-day data collection efforts. An ATC SME also participated in the first effort. The four data collection efforts are called ARTCC1[Pre], ARTCC1[Post], ARTCC2, and ARTCC3. ARTCC1[Post] indicates the same facility as ARTCC1[Pre], but after ERIDS was implemented. ARTCC3 was scheduled only for the paper system data collection.

2.1 Participants

We collected data from 67 participants but did not include data from two TMC personnel from ARTCC1[Post] because they indicated they accessed and used information differently than the controllers and FLMs. Of the remaining participants, 56 were male and 9 were female. Most of the participants in the paper data collection were controllers (n = 37); 10 were FLMs. All of the remaining participants in the ARTCC1[Post] effort were controllers. The median age of all the participants was 45, but the range of ages was slightly older for FLMs (29 to 60) than for controllers (26 to 54). Their total median years of ATC experience was 20 years for controllers and 21 years for FLMs. The years of experience ranged from 1 to 31 for controllers and from 8 to 36 for FLMs.

Table 1 shows the participant data for the individual data collection efforts (controllers and FLMs combined). The number of participants across the samples was unequal, but we exceeded our planned minimum of 12 volunteers during each visit. There was at least one and a maximum of four female participants in each effort. The FLM participants were distributed across all three paper sites. The median age and years of experience was lower for the ARTCC1[Post] site, which reflects the absence of the generally older and more experienced FLMs. In addition, one ARTCC1[Post] participant was still a developmental controller with only 1 year of experience. Although the participants' median age at ARTCC2 was similar to the participants' median age at the other ARTCCs that used paper documents, the minimum participant age was substantially older compared to the other facilities. Overall, the four samples appear to be sufficiently similar in their demographics therefore their data can be compared.

Table 1. Participant Demographics for Each Data Collection

	ARTCC1[Post]	ARTCC1[Pre]	ARTCC2	ARTCC3
Number	18	14	19	14
Number Male	16	10	17	13
Number FLMs	0	3	3	4
Median Age	41	46	46	44.5
Age Range	26-54	33-60	29-52	40-60
Median Experience	19	19.5	23	18.5
Experience Range	1-27	7-36	8-31	5-30

Note. FLMs = Front Line Managers. Age and experience data are in years.

2.2 Materials

We developed four paper documents to use during the data collection efforts. They were similar for all the efforts, but there were some differences between the Pre- and Post-ERIDS documents (e.g., questionnaires asked about using paper documents vs. ERIDS). In addition, some of the simulation questions contained local facility items. The example materials in the appendixes are from the ARTCC1[Post] data collection. First, we developed an informed consent form (see Appendix A) that described the project purpose and procedures, participant responsibilities and assurances, risks and benefits, guarantee of participant confidentiality, and what to do in the event of injury. The second was a background questionnaire (see Appendix B) to collect demographic data about each participant. The third was an ATC information questionnaire (see the first page in Appendix C) that asked the following five questions about six types of information.

1. *How frequently do controllers access the type of information?*
2. *How long does it take?*
3. *How difficult is it to access?*
4. *How important is it for ATC safety?*
5. *How important is it for ATC efficiency?*

The question types were ATC FAA Order 7110.65, Location Identifiers, Contractions, Approach Plates, SOPs, and LOAs. Finally, we developed a form (see Appendix D) to document our observations while we were on the operations floor.

We used a Dell D610 laptop computer to present the simulated data acquisition questions and to measure how long it took the participant to find the information. There were three questions each for six types of information in the questionnaires. The format of the questions was the same across the ARTCCs, but the specific elements (e.g., an airport approach, the facilities involved in LOAs, or an airspace location) were unique to each facility (see Appendix E for the ARTCC1 questions).[1]

2.3 Procedures

The ERAM program office obtained the cooperation of each facility and identified a point of contact (POC). The POC reserved space for the researchers to conduct the simulation exercise and to administer the questionnaires and meet with the participants. The POC also coordinated the recruitment of participants, scheduled floor observations with the Operations Manager and area FLMs, and arranged interviews with staff personnel. Upon arrival at the facility, the researchers met with the POC to coordinate the scheduling of participants and operations area observations.

As each participant arrived in the meeting room, a researcher explained the project to him or her and emphasized that participation was entirely voluntary. The researcher also explained that the participant could withdraw at any time without penalty, that there were no perceived risks to participation, and that individual identities would not be revealed to anyone outside of the research team. The participant then read and signed the informed consent form and filled out the background form. Then the researcher administered the simulation exercise followed by the questionnaire. If two participants overlapped, the order was reversed for the second controller.

The researcher explained the simulation task and provided either the paper documents or an ERIDS near the computer. The participant pressed the space bar, which started the timer, and a single question was presented. The participant used either the paper documents or the ERIDS to locate the requested information and then pressed the space bar again to stop the timer. If the participant found the correct information, the researcher reset the computer so that the participant could repeat the process with the next question. If the information was incorrect, the participant repeated the process with the same question, and the times were summed. To control the amount of time required to collect the data, we allowed a maximum of 5 min to find the correct answer for each question. The 18 questions were presented in a fixed order such that the participant answered one question of each type before repeating a type. There were also two orders (the second was the reverse of the first) that were presented to alternating participants. After each participant completed the questionnaire, the researcher asked for any additional comments, and many of them offered their observations or opinions.

At ARTCC1[Post], two members of the research team spent 8 hours (1 hour at a time) observing ATC operations area controllers. We observed once in each of the six operations areas, then an additional hour in two of the areas that used ERIDS most often. Each time we observed a

[1] During the ERIDS simulation exercise, the participants had great difficulty finding the three-letter designator for JetBlue Airways because they repeatedly inserted a space between Jet and Blue. After Participant 5, we modified the question so that the airline was Air Wisconsin. Unfortunately, the additional length of the airline name also caused problems, but both of these items identified human factors issues that should be mitigated through redesign.

controller seeking information in ERIDS, we recorded the sector, what type of information they sought (to the extent we could determine without interfering with the ATC operation), an estimate of how long the search took, and notes about the effort (e.g., whether it was the R-side or D-side controller seeking information, comments made by the controller, and what location they sought to identify). We also recorded which operations area we were in, the start and stop time of the observation period, which sectors were in the area, and what paper documents (paper backups are required even when the facility has ERIDS) were available in the area.

During the ARTCC1[Post] data collection, the Research Lead interviewed the Staff Specialist who led the effort to implement ERIDS and is responsible for maintaining the databases. The interview was open ended about the level of effort required for the system, as well as the paper system before ERIDS and as backup materials since ERIDS was implemented.

3. RESULTS

Not all participants provided usable responses to the questionnaire items. Because the question about frequency of access could be answered in terms of minutes, hours, shifts, or days, we converted all of the responses into number of times per shift (we assumed 5 hours working radar sectors per shift) so they could be compared across types of information. On some questionnaires, the responses were not sufficiently clear (e.g., "A few times per day" or "It varies") to be included in the database. Of the 390 possible responses over all information types, we could not interpret 32, which were treated as missing data. The question about how much time was required to access the information could be specified in seconds or minutes, so we converted all of the responses to seconds for comparability. We were unable to interpret only 10 of these responses. For this question, the distributions of responses were positively skewed (which occurs frequently with time-based measures, such as reaction time). Therefore, we compared the paper information responses to the grand mean for its information type and deleted outlier responses that were more than 3 *SDs* above the mean (3 *SDs* below the mean resulted in negative numbers). We compared the ERIDS responses to the overall ERIDS mean for each information type and removed any outliers. In the most extreme example, the mean for accessing Contractions was 86.4 s, but one respondent estimated it would take 20 min. This procedure resulted in the deletion of an additional 15 responses across all facilities and all information types.

The remaining three questions asked for ratings of difficulty to access each type of information and its importance to ATC safety and efficiency. On the questionnaires asking about the information in paper format, there were 10 missing responses. There were no missing responses for these questions about ERIDS. The response distributions for Questions 3 through 5 were normal. The number of valid responses is indicated in all the results.

During the ERIDS simulation data collection, one of the 18 participants did not attempt to find answers to some of the items; just saying, "Give me the maximum on that one." We retained this participant's questionnaire responses but did not include the simulation times in the database because of lack of effort. The timing data were also positively skewed; however, because of the 5-min cap, we did not use the outlier deletion procedure. Before statistically analyzing these data (and the estimated times for questionnaire Item 2, which remained skewed despite deleting the outliers), we first used a logarithm (log10 x_i+1; see Tabachnick & Fidell, 1989) transformation to normalize the distributions. For descriptive statistics, we present the untransformed means and *SDs* for ease of interpretation.

Two sets of analyses were conducted on the questionnaire and simulation data. First, we conducted Facility by Type of Information Analysis of Variance (ANOVA) on the three paper centers to determine if there were significant differences in how the participants accessed and used information across the different facilities. Second, we conducted a System by Type of Information ANOVA comparing the acquisition and use of information at the same facility (with paper vs. ERIDS). If there was a significant interaction, we do not present any main effects but focus on the interaction. Whenever there were significant ANOVA effects, we conducted post hoc analyses (either unequal N Tukey Honestly Significant Difference or t-tests when comparing only the two systems) to determine which elements differed from the others.

The results are presented in five subsections. The first subsection presents the analyses of the paper information questionnaire and simulation data, and the second subsection presents the analyses comparing ERIDS vs. paper information access and usage. The third subsection presents a summary of the observations in the operations areas. The fourth subsection summarizes the interview with a Staff Specialist at ARTCC1[Post] about the level of effort required to set up and maintain ERIDS compared to the former paper system. The final subsection describes human factors issues that we identified from our observations of ERIDS use, comments from participants, and the researchers' interactions with the system.

3.1 Paper Information Access and Usage Across Facilities

For the centers when they were still using paper documents, there was a significant interaction, $F(10, 243) = 2.05$, $p = .03$), between the facilities and information types in how frequently they accessed the information (Questionnaire Item 1). At ARTCC2, the participants reported accessing Approach Plates significantly more often than all of the other types, and at ARTCC1[Pre], the participants accessed Approach Plates more often than all other types except Location Identifiers (see Table 2). However, there were no significant differences at ARTCC3 in frequency of access between types of information. Within information types, the only significant difference between facilities was for LOAs, which ARTCC2 accessed less frequently than ARTCC3. Overall, the participants' responses indicate that they rarely access most types of information during a typical work shift, but there was high variability in the estimates.

Table 2. Frequency of Accessing Paper Information Types Per Shift Across Facilities

Information Type	**Facility**								
	ARTCC1[Pre]			**ARTCC2**			**ARTCC3**		
	n	**Mean**	***SD***	***n***	**Mean**	***SD***	***n***	**Mean**	***SD***
Air Traffic Control Order 7110.65	14	0.8	1.29	17	0.6	0.63	14	1.5	1.74
Location Identifiers	13	1.9	1.99	17	0.7	1.20	12	1.2	1.26
Contractions	14	0.5	0.79	17	0.3	0.40	11	0.6	1.46
Approach Plates	14	4.1	4.31	16	5.2	4.03	14	2.7	2.66
Standard Operating Procedures	14	0.5	0.77	18	0.2	0.34	13	0.8	0.80
Letters of Agreement	13	1.2	1.45	17	0.3	0.39	13	1.2	1.41

Note. ARTCC = Air Route Traffic Control Center.

There were significant effects of Facility, $F(2, 248) = 6.06$, $p = .003$, and Information Type, $F(5, 248) = 23.20$, $p <.001$, for the estimates of how long it takes to access information (see Appendix C, Questionnaire Item 2). The participants estimated that it took longer, on average, to access information at ARTCC3 ($M = 201.4$ s, $SD = 70.97$) than at ARTCC1[Pre] ($M = 173.2$ s, $SD = 75.15$) or ARTCC2 ($M = 165.2$ s, $SD = 71.89$). Across the facilities, Approach Plates took significantly less time to access ($M = 76.9$ s, $SD = 25.4$) than all other types, and Location Identifiers ($M = 119.6$ s, $SD = 11.8$) took less time than Contractions ($M = 184.0$ s, $SD = 18.9$), LOAs ($M = 203.3$ s, $SD = 28.9$), SOPs ($M = 232.0$ s, $SD = 53.2$), and the ATC Order ($M = 263.9$ s, $SD = 11.4$).

The results were similar for Questionnaire Item 3 on the difficulty to access paper information. Although the participants rated difficulty near the midpoint of the scale (i.e., *moderately difficult*) at each facility, the ratings were significantly higher, $F(2, 260) = 16.96$, $p < .001$, at ARTCC3 ($M = 5.9$, $SD = 2.35$) than at ARTCC1[Pre] ($M = 4.2$, $SD = 1.99$) and at ARTCC2 ($M = 4.4$, $SD = 2.10$). Across the facilities, Approach Plates ($M = 3.7$, $SD = 2.00$) were rated significantly easier to access, $F(5, 260) = 7.92$, $p < .001$, than the ATC Order ($M = 5.8$, $SD = 2.01$), SOPs ($M = 5.4$, $SD = 2.17$), and Contractions ($M = 5.0$, $SD = 2.26$). In addition, Location Identifiers ($M = 3.9$, $SD = 2.04$) were rated easier to access than the ATC Order and SOPs.

Questionnaire Items 4 and 5 asked the participants to rate the importance of each information type for safety and efficiency, respectively. The results were similar for both items (see Table 3). First, there were no significant differences between the facilities, but there were differences between types of information, $F(5, 261) = 48.41$, $p < .001$ for safety and $F(5, 261) = 18.27$, $p <.001$ for efficiency. Approach Plates were rated as highly important and more important for safety than all the other types of information. In addition, the ATC Order, LOAs, and SOPs were rated as more important for safety than Contractions or Location Identifiers. Approach Plates were also rated as most important for efficiency, but all the information types were rated above the midpoint of the scale. Contractions and Location Identifiers were rated as significantly less important for efficiency than the other four information types.

Table 3. Rated Importance of Paper Information Types for Safety and Efficiency

Information Type	**Rating Type**					
	Safety Rating			**Efficiency Rating**		
	n	**Mean**	***SD***	***n***	**Mean**	***SD***
Air Traffic Control Order 7110.65	47	8.0	1.99	47	7.6	1.95
Location Identifiers	46	4.1	2.37	46	6.1	2.31
Contractions	46	4.5	2.15	46	5.2	1.98
Approach Plates	47	9.3	0.98	47	8.6	1.79
Standard Operating Procedures	47	7.0	2.12	47	7.6	1.78
Letters of Agreement	46	7.4	1.93	46	7.7	1.75

Note. Ratings ranged on a scale from 1 (*not critical*) to 10 (*very critical*).

The participants had to find three items of each information type during the simulation exercise, so the number of data points at each facility is three times the number of participants (see Table 4). There were no missing data. There was a significant facility by information type interaction, $F(10, 828) = 5.90$, $p < .001$. At ARTCC1[Pre], Approach Plates were accessed significantly faster than all other information types, except LOAs, and LOAs were accessed faster than the ATC Order. At ARTCC2, LOAs, Approach Plates, and SOPs were accessed faster than Contractions, Location Identifiers, and the ATC Order. At ARTCC3, LOAs and Approach Plates were accessed significantly faster than Location Identifiers, the ATC FAA Order, and SOPS; Contractions were also accessed faster than SOPs.

Table 4. Simulated Access Times (in seconds) Across Facilities

Information Type	**Facility**					
	ARTCC1[Pre] (*n* = 42)		**ARTCC2 (*n* = 42)**		**ARTCC3 (*n* = 57)**	
	Mean	***SD***	**Mean**	***SD***	**Mean**	***SD***
Air Traffic Control Order 7110.65	70.7	50.04	100.2	88.21	95.4	75.52
Location Identifiers	62.3	50.53	72.7	68.67	86.8	62.13
Contractions	53.4	43.63	76.3	57.38	56.2	27.28
Approach Plates	34.5	18.83	36.9	17.61	48.0	41.03
Standard Operating Procedures	62.2	39.94	40.6	46.18	100.9	82.40
Letters of Agreement	45.6	28.24	32.8	22.51	39.9	18.85

There was no difference across facilities in accessing the ATC FAA Order, which generally took longer than most other types of information and had the most variability in access times across participants and individual items. The participants at ARTCC3 took significantly longer to access SOP information than at either of the other two centers, and longer to access Location Identifiers and Approach Plates than participants at ARTCC1[Pre]. Finally, the participants at ARTCC2 took significantly more time to access Contraction information and significantly less time to access LOAs than the participants at ARTCC1[Pre].

There was considerable consistency between the questionnaire data and the simulation data. For example, Approach Plates were rated as being used most often, were easiest to access, and were most important for safety and efficiency. Approach Plates were accessed in the simulation more rapidly than the other information types except at ARTCC3, but there were no differences at that facility in the rated frequency of access and the overall rated difficulty of accessing information was significantly higher than at the other two. Finally, the participants at ARTCC1[Pre] were faster at accessing all types of paper information than the participants at one or both of the other centers, although the differences were not always statistically significant because of the high degree of variability in the data.

3.2 ERIDS vs. Paper Information Access and Usage at ARTCC1

There was a significant interaction between information delivery system and information type, $F(5, 167) = 3.59$, $p = .004$, in the rated frequency of access. With the paper system, Approach Plates were accessed significantly more often than all other information types except Location Identifiers (see Table 5). With ERIDS, Location Identifiers and the ATC Order were accessed significantly more often than SOPs and LOAs; Location Identifiers were also accessed more often than Contractions. The ATC Order and Location Identification information was accessed more frequently with ERIDS than with paper. There were no statistically significant differences in access between the delivery systems for the other four types of information. The variability in rated frequency of access for the ATC Order and Location Identifiers with ERIDS indicates that some participants still did not access them often while other participants accessed them quite frequently.

Table 5. Frequency of Accessing Information Types with Paper and ERIDS

Information Type	**Information System**					
	Paper			**ERIDS**		
	n	**Mean**	***SD***	***n***	**Mean**	***SD***
Air Traffic Control Order 7110.65	14	0.8	1.29	16	6.9	9.15
Location Identifiers	13	1.9	1.99	17	8.3	8.81
Contractions	14	0.5	0.79	15	0.8	0.88
Approach Plates	14	4.1	4.31	17	5.2	5.36
Standard Operating Procedures	14	0.5	0.77	16	0.6	0.61
Letters of Agreement	13	1.2	1.45	16	0.9	0.68

Overall, the participants estimated that it takes significantly longer, $F(1, 167) = 118.23$, $p < .001$, to access information with paper documents ($M = 173.2$ s, $SD = 75.15$) than with ERIDS ($M = 57.0$ s, $SD = 32.77$). Across both delivery systems, Approach Plates ($M = 42.4$ s, $SD = 27.89$) and Location Identifiers ($M = 59.7$ s, $SD = 67.16$) were estimated as significantly faster to access, $F(5, 167) = 8.31$, $p < .001$, than SOPs ($M = 156.6$ s, $SD = 118.00$) or the ATC Order ($M = 175.8$ s, $SD = 110.40$). The results were very similar for Question 3, the estimated difficulty of accessing information. Paper information ($M = 4.2$, $SD = 1.99$) was rated as significantly more difficult to access, $F(1, 179) = 15.43$, $p < .001$, than information in ERIDS ($M = 3.1$, $SD = 2.17$). The average difficulty of both systems was below the midpoint, indicating less than moderate difficulty. Location Identifiers ($M = 2.3$, $SD = 1.81$) and Approach Plates ($M = 2.5$, $SD = 1.46$) were rated as significantly easier to access, $F(5, 179) = 8.21$, $p < .001$, than SOPs ($M = 4.6$, $SD = 2.38$), the ATC FAA Order ($M = 4.4$, $SD = 1.97$), and Contractions ($M = 4.3$, $SD = 2.09$). Even the most difficult type of information was rated only at the midpoint of the scale, although the variability in the ratings indicates that some participants found it much more than moderately difficult to access some of the information types.

The results of the ratings of importance for safety and efficiency were very similar to the paper-only ratings (cf. Table 3 and Table 6), in part, because half of the data (i.e., ARTCC1[Pre]) was identical in both analyses and, in part, because the importance of the information for operations should not change as a function of the source. As expected, there were no significant differences between the information delivery systems, but there were differences between types of information, $F(5, 179) = 20.63$, $p < .001$ for safety and $F(5, 179) = 10.70$, $p <.001$ for efficiency. Approach Plates were rated as highly important and more important for safety than all the other types of information. In addition, the ATC Order, LOAs, and SOPs were rated as more important for safety than Contractions or Location Identifiers. Approach Plates were also rated as most important for efficiency and significantly more important than Contractions, Location Identifiers, and SOPs. LOAs were rated as significantly more important than Contractions and Location Identifiers, and the ATC Order was rated as more important than Contractions.

Table 6. Rated Importance of Information Types for Safety and Efficiency

Information Type	Rating Type					
	Safety Rating			Efficiency Rating		
	n	Mean	*SD*	*n*	Mean	*SD*
Air Traffic Control Order 7110.65	32	7.3	2.72	32	7.4	2.71
Location Identifiers	32	4.3	3.07	32	6.0	2.87
Contractions	32	4.3	2.55	32	5.0	2.53
Approach Plates	32	9.3	0.98	32	8.9	1.51
Standard Operating Procedures	32	6.4	2.78	32	7.0	2.27
Letters of Agreement	31	7.6	2.10	31	7.8	1.74

Note. Ratings ranged on a scale from 1 (*not critical*) to 10 (*very critical*).

There was a significant delivery system by information type interaction, $F(5, 546) = 9.19$, $p < .001$, in the simulated access times (see Table 7). Using ERIDS, the participants were significantly slower at accessing SOP and ATC Order information than the other types of information. Using the paper documents, the participants accessed Approach Plates more rapidly than the ATC Order, SOP, Location Identifier, and Contraction information. They also accessed LOA information faster than the ATC Order. The participants accessed SOP and ATC Order information faster using paper documents but were faster with ERIDS at accessing Approach Plates, Contractions, and Location Identifiers. There was no difference between systems for LOAs.

Table 7. Simulated Access Times (in seconds) Using Paper vs. ERIDS at ARTCC1

Information Type	Information System			
	Paper (*n* = 42)		ERIDS (*n* = 51)	
	Mean	*SD*	Mean	*SD*
Air Traffic Control Order 7110.65	70.7	50.04	112.2	86.09
Location Identifiers	62.3	50.53	51.2	23.16
Contractions	53.4	43.63	43.4	23.12
Approach Plates	34.5	18.83	27.8	19.89
Standard Operating Procedures	62.2	39.94	116.5	85.08
Letters of Agreement	45.6	28.24	44.6	28.64

Note. ERIDS = En Route Information Display System.

There were some discrepancies between the questionnaire data and the simulation data. Primarily, the participants rated the paper documents as taking longer to access and as more difficult to access than ERIDS, but the performance data found that effect for only three of the information types; participant performance was faster using paper documents on two of the other types. However, the participant ratings included estimates of the time to locate the documents, but the documents were readily available in the simulation exercise. In addition, the participants at ARTCC1 were generally faster at accessing all types of paper information than the participants at the other centers.

3.3 Operations Area Observations

Collectively, two researchers observed operations for eight 1-hour periods. They observed each of the six operations areas at least once. The two additional observation periods were in areas that the Operations Manager thought were most likely to use ERIDS. Each area had between six and eight sectors of airspace. All areas had paper backup copies of all the required information, but no one was observed using any of them. During the 8 hours, we observed controllers using ERIDS to obtain information only 79 times, although they occasionally relocated the display to accept flight strips or to go on a break. There were no observed usages in one area, and it was used only by two sectors in another area. In the other four areas, we observed the controllers using ERIDS at most or all of the sectors. Nonetheless, this represents very limited utilization of ERIDS to acquire information. We observed several positions with Messages waiting that were never accessed.

It was not always possible to determine exactly what information the controller was accessing. Unless the observer was at the sector, the entire search could end before being close enough to determine what the actions were. The most common usage was the Lookup function (noted 28 times), but it led to submenus where the controller can find facility names, locations, radio frequencies, published approaches, NAVAIDs, and so on. The second most frequent usage was for Approach Plates (noted 15 times). There were 12 notations of searching for LOAs and 4 each for the ATC Order, company call signs, and aircraft information. Searching for NOTAMs was noted 3 times. The remaining items were single notations and may have been subsets of the others caused by the researchers using different notations or by observing only part of the process (e.g., one was listed as SID/STAR search, which was probably an Approach Plate, and notes for NAVAIDs search and location were probably done through the Lookup function).

Most of the searches were performed quickly, usually within 20 seconds (the times were estimated). The longest estimated-use times (five instances lasting more than 1 minute) were for searching the ATC Order, an LOA, for an airport, or for an Approach Plate. In two of those instances, the researcher noted the controller was either not on position or was a D-side controller. On the two instances of an Approach Plate, the controller continued to use it over time for the approach.

3.4 Setup and Maintenance of ERIDS Information

According to the Staff Specialist, the initial setup of ERIDS was arduous and there were many baseline issues to work out, especially with respect to the Oracle databases. These issues, which were unique to the key (first) site, delayed implementation by several months. Technical Operations also would not accept the system because there was no backup. There are two environments (Production and Training) that had to be built and maintained. The local area and sector binders had to be built twice, once for each environment. Originally, the system was to have the capability to copy one into the other, but it was not implemented. Overall, the first build took three people approximately 4 weeks to complete. The second build was easier because of the experience gained; it required two people approximately 2 weeks to complete.

The national documents (e.g., FAA Order 7110.65) are updated as needed (approximately three times a year) and Approach Plates are updated every 28 days. Before ERIDS, the national documents and Approach Plates were ordered in hard copy. It took about 5 staff hours every 2 months to copy and distribute changes to the operational areas. Previously, they copied and replaced only the Approach Plates that had changed. Because expiration dates now appear on the edge of the plates, they must replace the entire booklets. They now order six booklets (one per area) rather than just two. They are working on an electronic backup on the sector computers in case the ERIDS database fails, so that they can reduce the paper backups currently required.[2]

With ERIDS, the facility receives the national documents and Approach Plates on a DVD. It takes 30-60 minutes of staff time to test and verify the data and about 2 minutes to initiate the change using a script. It takes approximately 30 minutes to load the data, but no personnel time is involved. Overall, the system works very well for maintaining national documents and Approach Plates. GENOTs about changes to national documents are not linked to the documents themselves, but they are pursuing this capability.

Changes to local documents varies over time and events. For example, when a new company took over all the contract towers, the ARTCC created standardized LOAs. The standardization was beneficial, but it created changes to charts and Approach Plates that affect local documents. The first step in making the change is for Staff Specialists to draft a new document, which must then be entered in the paper and electronic systems. The original paper document must be written in Times New Roman font. Once written, it takes approximately 3 staff hours to print and distribute the new document and update the indexes. For ERIDS, the Staff Specialist must convert the paper document to Ariel font and PDF format, save it on a thumb drive, load it into the database, and update the index. This takes about 30 minutes of staff time to complete.

There are three types of NOTAMs: Local (L) NOTAMs affect local areas (e.g., personnel working on part of an airport) but do not generally represent a landing hazard; Distant (D) NOTAMs (e.g., a runway closure) affect the safety of landings and takeoffs; and Flight Data Center (FDC) NOTAMs (e.g., temporary flight restrictions) affect Approach Plate procedures. The L NOTAMs are received at the center by telephone, facsimile, or email. The D and FDC NOTAMs are received via the AIS-R. Flight Data Specialists monitor the receipt and distribution of the NOTAMs.

Before ERIDS, the Specialists monitored the AIS-R for FDC NOTAMs and queried the AIS-R every 3 hours (between 6 a.m. and 9 p.m.) for D and FDC NOTAMs affecting the Center's area of responsibility. They printed and distributed them to the Operations Manager in Charge (OMIC) and to the FLMs of affected areas of specialization. The schedule for querying the AIS-R means that a D or FDC NOTAM may have been as much as 3 hours late in being distributed. Because L NOTAMs did not affect the safety of flight, they were generally ignored.

[2] This change has subsequently been implemented.

If Tech Ops and the ERIDS administrator verify through a random comparison of electronic and printed NOTAMs that ERIDS is operationally viable, the OMIC declares its operational use. ERIDS polls the AIS-R every 5 min seeking new or cancelled D and FDC NOTAMs and loads them into system, which automatically distributes them to affected sectors. The process takes seconds. Now, however, Flight Data Specialists are required to enter L NOTAMs into ERIDS and determine which sectors should receive them. This adds to their workload compared to the paper-only system. The Flight Data Specialists consider the two systems equivalent in terms of the level of effort required. There are plans to distribute L NOTAMs the same way as the other NOTAMs, so eventually it would be completely automated.

3.5 Human Factors Issues with ERIDS

This section describes some human factors issues the researchers observed while watching controllers on the floor and participants during the simulation exercise or by interacting with the system when no participants were available. In addition, we obtained numerous comments during our interviews with the participants and occasional comments by controllers working their sectors.

Overall, most of the controllers and staff indicated that ERIDS is a good system, even though they use it to access only a few types of information on a regular basis. Several commented that controllers at low altitude sectors use ERIDS the most and that super high sectors almost never use it. The low altitude sectors are most likely to need Approach Plates and airport and Location Identifier information. Some managers and staff commented that the younger controllers used ERIDS more often than the older controllers, but the correlation between age and the speed of accessing information in the simulation exercise was not statistically significant. Another participant commented that ERIDS is an excellent tool for training because they could search for a reference about the topic of training at the position. There were, however, a number of human factors issues with the system that could be improved either through system modification or training. We first present the issues about the system in general, and then we discuss issues about specific buttons and features.

The researchers identified three potential physical problems with the system. First, the display is fairly large and heavy, it is black in color, and it is difficult to see in the dark environment of the operations floor where there are multiple electronic systems. Several participants commented that controllers had hit their heads on the displays, and that one had been unable to work for an extended time because of the injury. We observed that the displays were usually stowed high and away from the radar display, which reduces the chance of injury, but also makes the display more difficult to see (e.g., if there are new messages pending). Second, some of the controllers commented that the articulating arms did not work well and, over time, did not maintain their position. A finding of an Independent Operational Test and Evaluation review of ERIDS prototypes (Lewis, 2006) was that current FAA orders do not require preventive maintenance on the articulating arm beyond quarterly tightening of the attaching screws. Others reported that the arms were not a problem, and the researchers did not observe any problems with the arms. However, the functionality of the arms should be monitored. Finally, several participants commented that the ERIDS display was not kept clean (touching it repeatedly with fingers leaves residues of oil and dirt on the screen), so they had to touch a button multiple times to make contact. The simulation participants commented that the displays used in the training laboratory for the simulation exercise were in better condition than the displays used in the operations area.

We noted that the color coding of buttons was not consistent internally (e.g., buttons that produce an action or lead to a submenu) or with widespread interface design guidelines (e.g., graying out buttons that are not available). That is, the controller could press buttons that led to nothing, either because the function was not enabled or the database was not populated. The organization of some pages was not logical, which made it difficult for controllers to find information or required multiple steps to access the information. For example, if the controller pressed the Search button and then the SID/STAR button, it would lead to the Lookup button, making the first two steps unnecessary.

The controllers could interact with the system by using their fingertip or a stylus, or both. There were advantages and disadvantages to each method, which is discussed further on the individual buttons. In general, using the finger produced better results for scrolling and dragging through lengthy documents and for entering data using the soft keyboard. The stylus was better for selecting chapters from the table of contents or "jump to" letters of an index, because the font size was too small and the text was too close together to select with a fingertip. We observed that approximately one-third of the simulation participants used each interaction method (these are qualitative assessments by the researcher who conducted the simulation exercises; we did not collect objective data about the different interaction methods). The participants who used both generally performed the best, whereas those who used only their fingertip had the most difficulty. Using both optimized the advantages of each method but required picking up and putting away the stylus with each change.

Scrolling and dragging was difficult with the default Normal view. When scrolling, the display would jump from one page to the next as soon as the top of the page was reached. Dragging could be done only within a page, not across pages. We discovered that both problems were eliminated by changing to the Print Layout view, but we did not observe any of the participants changing the default setting. Finally, entering data, especially with the soft keyboard, was difficult. Entries frequently did not register, and repeated attempts were required to accomplish the entry. Errors were frequently made when entering a lengthy string of characters (e.g., for a search entry), and the errors were difficult to correct. The participants frequently would just start the entry over again. Lewis (2006) noted there was no order requiring preventive maintenance for calibrating the touchscreens beyond cleaning as required. In addition, the text box on the soft keyboard did not expand to provide feedback on entry success if the string was longer than the box (e.g., Air Wisconsin).

At the time of this evaluation, only NOTAMs were displayed on both the Home page and via the Messages page. ERIDS automatically polls, distributes, and cancels the D and FDC NOTAMs much more frequently than when Flight Specialists had performed it manually. The participants indicated that NOTAMs are a useful function in ERIDS, but there are a few problems with the current system. First, the indication (flashing border and number of unread messages on the Messages button) that there is a pending message is not very salient (especially if the display is stowed out of direct view). The participants reported and we observed that they rarely checked the NOTAMs, unless they were controlling a landing airplane. Second, the D NOTAMs affect the safety of landing, and the FDC NOTAMs can affect the information on Approach Plates.

The participants reported concerns about the reliability and timeliness of these NOTAMs on the Home Page and Messages pages, and they indicated that they take the extra steps to check the NOTAMs on the Airport Lookup page to be certain. Lewis (2006) reported a similar issue for NOTAMs about NAVAID outages because the name of the aid may not be the same as the airport, and they may not be fully cross-referenced. However, many participants expressed the opinion that navigation outages were not as important as in the past, because of the flight deck area navigation equipment and because pilots are responsible for getting briefed on NOTAMs before takeoff.

The Home page and Messages page may contain many NOTAMs, there is little space between each line of text, and the text is cryptic (shown in Figure 3), so finding and reading relevant information may be difficult. The NOTAMs are in order of receipt and, at the time of this evaluation, there was no indication of relative importance. Subsequently, a new format has been implemented for NOTAMs so that one of 12 keywords will be included in a consistent location so that at least the type of information can be determined (Parsons, 2008). Now, there are also pointer NOTAMs that lead to more detailed, published information.

The Weather button currently allows only the entry of PIREPs, but even that function is no longer enabled because it was too difficult and time consuming for the controller to enter all the required information. At the time of this evaluation, they were still using paper PIREPs. Several simulation participants stated they would like to have weather information available on ERIDS, but FAA Notice 7210.653 prohibits the display on ERIDS of dynamic operational information including weather. As a result, this function is not in use.

The participants indicated that they do not access the ATC documents very often and prefer to use the backup paper documents when they do, especially the ATC Order, which is difficult to use in ERIDS. In many of the documents, the controller can select only chapters because there is no alphabetical index of topics with an associated page number as there is in the paper document. The chapters listed in the table of contents are in a small font size and the chapter titles have little space between them so it is difficult to select one without using the stylus. Once the chapter is accessed, the controller must scroll or drag the pages to find the relevant information. As mentioned earlier, unless the controller knows to change the default view setting, it is difficult to scroll or drag, especially with the stylus. There was a browse (search) function, but it did not work well. It returned lines of text that contained the keyword(s) from all the documents in the selected database (core, all national, all local, or all) without indicating the source and with insufficient text to determine its applicability. The controller had to click on each return to get additional context, which was time consuming if there were multiple hits. Some ATC documents, especially Location Identifiers and Contractions, were somewhat easier to use within this database.

The only information available in the Charts database were sectional charts that are large and contain a great amount of detail. It took approximately 15 s to 20 s for a sectional chart to load in the display, which was faster than expected. Lewis (2006) reported that displaying and zooming sectional charts was “extremely slow” but then the user must pan and zoom in to find the specific information needed. The dynamic zoom, scroll, and drag capabilities were better than expected; Jha and Sollenberger (2005b) found these charts to be difficult to use. However, the controllers reported that they rarely use the charts.

Pressing the Search button led controllers to a submenu that had buttons for Aeronautical Contractions, Facility and Airport information, aircraft information, call sign and company information, SIDs/STARs, and custom pages. The contractions search was easy to use. There was a lot of useful information about facilities and airports (e.g., approach plates, radio frequencies, NAVAIDs, and runways and taxiways), but it could take several clicks to access specific pieces of information. The information could also be searched using the Lookup button. As previously mentioned, pressing the SID/STAR submenu button simply led to the Lookup button. The aircraft information search could be confusing because the controller must press a radio button to indicate the type of information before executing the search, but it is not clear whether to press the button for what is known and entered as the search string or what information is being sought. For example, if a controller wants to know who the manufacturer of the A748 is, the user must enter A748 and press the Type radio button. Finding company information was inflexible, and the controllers were not aware of an important capability. When searching for JetBlue during the simulation exercise, the company name had to be entered as a single word with no space. When most participants typed Jet Blue, the search returned nothing. Many search engines have much more flexibility. After the first day of the exercise, we changed the company to Air Wisconsin, which did not make the task faster or less frustrating for the subsequent participants but did identify other human factors issues. Typing the longer search string led to more entry errors and retries because the full term did not fit within the keyword box, so there was no feedback about the accuracy of entry, and the participants did not realize that the entire company name did not have to be entered to perform the search. In this case, entering “Air W” returned a list of seven companies (including Air Wisconsin), which could then be selected.

The Lookup function was generally easy to use, except for the problems noted about entering data via the soft keyboard. This was particularly true for accessing Approach Plates, which was used relatively frequently in low altitude sectors. Because of the size of each Approach Plate, the entire plate was not displayed, and the controllers had to scroll to see information at the bottom. Another issue the participants raised was that they sometimes needed to switch back and forth between multiple plates, but that could not be accomplished with the Back button and there was no Forward button.

The Area Shortcuts (sector binders) are created and maintained by Staff Specialists and contained all the required LOAs and SOPs, and the participants stated they were easy to access. They mentioned that some of the difficulty they had in finding LOA information in the simulation exercise was because LOAs are generally specific to the sector or at least the operations area, so they would be more familiar with them than the ones in the exercise. The SOPs document was lengthy, and the controllers had to find information using a table of contents and then scroll to the relevant chapter; there was no direct link to the chapter as there is in the ATC Order. Especially if the sought information was located in the latter part of the document, scrolling to it created problems. When scrolling fast, the controller could not read the passing information to determine the current location in the document. When scrolling slowly enough to determine the location, it could take an excessive amount of time to reach the location.

The position shortcuts are created by the controller for information that is needed regularly. The participants indicated they were very useful, but if other controllers eliminate them in favor of theirs, they must be recreated by the first controller when next working the sector. All position shortcuts are also eliminated if there is a system update. There was no capability for creating and restoring individual shortcut preferences at a sector.

We did not use or receive any comments about the Resector, Create Shortcuts, and Help functions. There may be other human factors issues or other valuable capabilities in the system that we did not have the opportunity to observe or were not reported to us by the participants. The issues reported here were not based on a formal human factors evaluation but were observations or comments obtained during the other data collection activities. In addition, there may have been further changes to the system since we conducted this evaluation.

4. DISCUSSION AND RECOMMENDATIONS

All of the assessments of ERIDS indicate that controllers do not regularly obtain and use relatively static aeronautical information whether it is available in paper or electronic format. There were some differences between ARTCCs in how frequently and how quickly participants accessed information using the paper system, especially for Approach Plates, but these may be a function of the airspace and sector characteristics. Controllers at some sectors do need this information more often and need it quickly when they do (e.g., a low altitude sector where a plane is on approach to land). In those instances, ERIDS is definitely beneficial. ERIDS eliminates the problem with paper documents not being readily available, which was the most time consuming part of the information acquisition process. With ERIDS, the information is always available at the sector position. In addition, accessing Approach Plates, the most frequently sought and highest rated type of information for safety and efficiency, is easy to do with ERIDS, unless the controller needs to switch between two or more plates. In addition, D and FDC NOTAMs, which can affect the safety of landing and use of Approach Plates, are updated much more frequently in ERIDS than they were in the paper distribution system, although there are concerns (not noticing new messages, no indication of importance, difficulty reading, and lack of cross references between NAVAIDs and airports with different names) about accessing them on the Home or Messages pages. Providing a capability to have multiple Approach Plates in concurrent use and improving the NOTAMs process would be beneficial enhancements to ERIDS.

Access to Location Identifiers, Contractions, and LOAs also appears to be faster with ERIDs, especially when the time required to find the paper documents is taken into account. The participants reported that having shortcuts to LOAs, which were rated as more important for safety and efficiency than the other information types except Approach Plates, was beneficial even though our simulation exercise did not show any difference in time to find LOA information. During the exercise, several participants commented that they were searching for unfamiliar LOAs without the shortcuts. The participants indicated that they accessed Location Identifiers more frequently in ERIDS than when they used the paper document. Location Identifiers were rated as being somewhat more important for efficiency than for safety, so the controllers may use them more now that they can be accessed more quickly. Once the initial ERIDS setup is complete, there are benefits in maintaining the currency of the information and in staff time to copy, distribute, and destroy paper documentation. The benefits in staff time are currently limited by the requirement to maintain backup paper documents and to manually process L NOTAMs. Finally, the participants and some supervisors told us that ERIDS was beneficial for training.

Although now available at the sector, locating information in the ATC Order and SOPs is actually more difficult and time consuming in ERIDS. There are four problems that need to be addressed to make information acquisition easier and faster with these and other voluminous documents. First, the browse and search capability needs to be improved. Second, these documents need an index of keywords (as they have in their paper format) hyperlinked to the specific page where the information is located. Third, the links from the table of contents chapters need to be larger and easier to select (e.g., more space between the chapter titles). Finally, the problems with scrolling and dragging should be remedied or, at least, make the Print Layout the default setting or train the controllers to change the setting.

We reported other human factors issues with the ERIDS, but these were based on our observations and interviews, not a formal evaluation. There are straightforward solutions to many of them. For example, nonfunctioning features (e.g., Weather) should be activated, removed, or at least grayed out to indicate that they are not currently functioning. The user interface for the Search function should be improved (e.g., clarify what the radio buttons indicate and make the company search more flexible); otherwise, training on how to use it should be provided. Certainly, the articulating arms and touchscreen calibration should be adequately maintained, and procedures should be implemented to stow the display in such a way that it poses no safety risk yet is clearly visible. Our most important recommendation is that a more thorough human factors evaluation be conducted to identify and prioritize other issues as well as to make recommendations for addressing them. Overall, ERIDS is beneficial; however, these improvements should make it even more useful.

References

Federal Aviation Administration. (2003). *Benefits basis of estimate (BOE) for en route automation modernization (ERAM)*. Washington, DC: Author.

Federal Aviation Administration. (n.d.). *Aeronautical Information Manual*. Washington, DC: Author. Available from FAA Web site, http://www.faa.gov/airports_airtraffic/air_traffic/publications/ATpubs/AIM/

Federal Aviation Administration. (n.d.). *Air Traffic Control* (DOT/FAA/Order 7110.65). Washington, DC: Author. Available from FAA Web site, http://www.faa.gov/regulations_policies/ orders_notices/air_traffic_orders/

Federal Aviation Administration. (n.d.). *Contractions* (DOT/FAA/Order 7340.1). Washington, DC: Author. Available from FAA Web site, http://www.faa.gov/regulations_policies/orders_notices/air_traffic_orders/

Federal Aviation Administration. (n.d.). *Facility Operation & Administration* (DOT/FAA/Order 7210.3). Washington, DC: Author. Available from FAA Web site, http://www.faa.gov/regulations_policies/orders_notices/air_traffic_orders/

Federal Aviation Administration. (n.d.). *Interim Air Traffic Procedures for En Route Information Display System (ERIDS)* (DOT/FAA/Order 7350.7). Washington, DC: Author. Available from FAA Web site, http://www.faa.gov/airports_airtraffic/air_traffic/publications/at_notices/media/N7210.653.pdf

Federal Aviation Administration. (n.d.). *Location Identifiers* (DOT/FAA/Order 7350.7). Washington, DC: Author. Available from FAA Web site, http://www.faa.gov/regulations_policies/orders_notices/air_traffic_orders/

Jha, P., & Sollenberger, R. (2005a). *En route air traffic controllers non-radar display information need analysis: Results of a cognitive walkthrough*. Unpublished manuscript.

Jha, P., & Sollenberger, R. (2005b). *Human factors benefits assessment of en route informational display system for controller performance: Analytical results.* Unpublished manuscript.

Lewis, A. (2006, July). *En Route Information Display System (ERIDS) IOT&E results brief.* Washington, DC: Office of Independent Operational Test and Evaluation.

O'Hara, K., & Sellen, A. (1997). A comparison of reading paper and online documents. *Proceedings of CHI '97* (pp. 335-342). New York: ACM Press.

Parsons, S. (2008, January/February). Know your NOTAMs: Introducing the new "Super D." *FAA Aviation News*, *47*, 10-14.

Rodgers, M., & Dreschsler, G. (1993). *Conversion of CTA Inc - En route operations concept database into a formal sentence outline job task taxonomy* (DOT/FAA/AM-93/1). Washington, DC: Federal Aviation Administration Office of Aviation Medicine.

Sollenberger, R., Koros, A., & Hale, M. (2008). *En route information display system benefits study* (DOT/FAA/TC-08/06). Atlantic City International Airport, NJ: FAA William J. Hughes Technical Center.

Tabachnick, B. G., & Fidell, L. S. (1989). *Using multivariate statistics* (2nd ed.). New York: HarperCollins, Inc.

Acronyms

AIM	Aeronautical Information Manual
AIS-R	Aeronautical Information System - Replacement
ANOVA	Analysis of Variance
ARTCC	Air Route Traffic Control Center
ATC	Air Traffic Control
D	Distant
D-side	Data-side
DSR	Display System Replacement
ERAM	En Route Automation Modernization
ERIDS	En Route Information Display System
ESIS	Enhanced Status Information System
FAA	Federal Aviation Administration
FDC	Flight Data Center
FLM	Front Line Manager
GENOT	General Notice
GI	General Information
JTA	Job-Task Analysis
L	Local
LOA	Letter of Agreement
NAS	National Airspace Lab
NAVAID	Navigation Aid
NOTAM	Notice to Airmen
OMIC	Operations Manager in Charge
PDF	Portable Document Format
PIREP	Pilot Weather Report
POC	Point of Contact
RENOT	Regional Notice
R-side	Radar-side
SD	Standard Deviation
SID	Standard Instrument Departure
SIGMET	Significant Meteorological Information

SME	Subject Matter Expert
SOP	Standard Operating Procedure
STAR	Standard Terminal Arrival Route
SUA	Special Use Airspace
TFM	Traffic Flow Management
TMC	Traffic Management Coordinator
TRACON	Terminal Radar Approach Control
WJHTC	William J. Hughes Technical Center

Appendix A

Informed Consent Form

ERIDS Benefits Study

Informed Consent Form

I, ______________________________________ (please print), understand that this project, entitled "En Route Information Display System (ERIDS) Benefits Study" is sponsored by the Federal Aviation Administration and is being directed by Dr. Mike McAnulty. Dr. McAnulty is an engineering research psychologist at the FAA William J. Hughes Technical Center.

Nature and Purpose:

I have been recruited to volunteer as a participant in this project. The purpose of this study is to investigate the benefits of ERIDS primarily to air traffic controllers, but also to supervisors and traffic management personnel. The study will also examine the impact of ERIDS on support staff personnel who maintain the required information.

Study Procedures:

Three researchers will conduct four different data collection activities at the Center for three days. First, they will observe controllers on position during live operations and will record data describing controllers' use of ERIDS and reference manuals to access needed information. Second, a researcher will conduct simulations asking controllers to find specific information using ERIDS. A laptop computer will be used to present questions to the controllers and timing their responses. Third, the controllers will be asked to complete a questionnaire about how frequently they access specific types of information, how much time it takes, and how critical the information is. In the last activity, a researcher will interview staff personnel who are responsible for supporting ERIDS and the backup paper information. The researchers will collect data about the level of effort and costs required to maintain both systems.

Discomfort and Risks:

I understand that I will not be exposed to any foreseeable risks or intrusive measurement techniques.

Confidentiality:

My participation is strictly confidential, and no individual names or identities will be recorded or released in any reports.

Benefits:

I understand that the only benefits to me are that I will be able to provide the researchers with valuable feedback and insight into ERIDS costs and benefits.

Participant Responsibilities:

I am aware that to participate in this study I must be a full professional level controller, supervisor, or traffic management employee. I may also be a staff employee who is responsible for ERIDS support or processing other sources of ATC information. I will answer any questions asked during the study to the best of my abilities.

Participant Assurances:

I understand that my participation in this study is completely voluntary, and I may withdraw at any time without penalty. I also understand that the researchers may terminate my participation if they believe it to be in my best interest. I understand that if new findings develop during this study that may affect my decision to continue participation, I will be informed.

I have not given up any of my legal rights or released any individual or institution from liability for negligence.

I understand that the members of the research team will answer any questions I have about this study, my participation, and the procedures involved.

Compensation and Injury:

I agree to immediately report any injury or suspected adverse effect of participating in this research to Dr. McAnulty at (609) 485-5380. Local clinics and hospitals will provide any treatment, if necessary. I agree to provide, if requested, copies of all insurance and medical records arising from any such care.

Signature Lines:

I have read this informed consent form, understand its contents, and freely consent to participate in this study under the conditions described. I understand that, if I want to, I may have a copy of this form.

Participant: ____ Date:__________

Researcher: ____ Date:__________

Witness: ____ Date:__________

Appendix B

Background Questionnaire

ERIDS Benefits Study

Background Questionnaire

Instructions:
This questionnaire is designed to obtain information about your background and experience. The information will be used to describe the participants in this study as a group. You will not be identified by name. Indicate your response by specifying the information in the blank line provided or by filling in (or mark with an X) the circle.

1. What is your job position?

○ Certified Professional Controllers ○ Supervisor ○ TMC ○ Support Staff ○ FDCS

2. What area do you work? ___________ specify

3A. If you are a Certified Professional Controller:

How many years of experience do you have at your current position? _____ years

3B. If you are a Supervisor / TMC:

How many years did you work as a Certified Professional Controller? _____ years

How many years have you worked as a Supervisor / TMC? _____ years

3C. If you are a Support Staff Employee or FDCS:

How many years have you worked at your current position? _____ years

4. Who do you work for? ○ FAA ○ Contractor

5. What is your gender? ○ Male ○ Female

6. What is your age? _____ years

Appendix C

ATC Information Questionnaire

ERIDS Benefits Study

ATC Information Questionnaire

Instructions:
For the source of information at the top of each page, indicate your response by specifying a number in the blank line provided or indicate your rating by filling in (or mark with an X) a numbered circle.

7110.65 Air Traffic Control

1. How frequently do controllers access this information when using paper reference manuals? (specify number of times per minute, per hour, per 8-hour day, or once every number of days)

____

2. How long does it take controllers to access this information using paper reference manuals? (specify number of seconds or minutes)

____

3. How difficult is it to access this information when using paper reference manuals?

Not Difficult ① ② ③ ④ ⑤ / ⑥ ⑦ ⑧ ⑨ ⑩ Very Difficult

4. How important is this information for ATC safety?

Not Critical ① ② ③ ④ ⑤ / ⑥ ⑦ ⑧ ⑨ ⑩ Very Critical

5. How important is this information for ATC efficiency?

Not Critical ① ② ③ ④ ⑤ / ⑥ ⑦ ⑧ ⑨ ⑩ Very Critical

Appendix D

ERIDS Operational Observation
Data Collection Form

ERIDS Benefits Study

ERIDS Operational Observation - Data Collection Form

Date: ______________ Area: ____________________________________ Start Time: ____________ Start Time: __________

Identify the type and location of any hardcopy materials available: ____

____

____

____

____

Other Notes: ____

____

____

____

Sector	**Usage Time (seconds)**	**What info was accessed**	**Notes** **(How info was accessed, speed to open, ease of selecting item, etc.)**

Appendix E

ERIDS Simulation Questions

ERIDS Benefits Study

ERIDS Simulation Questions for ARTCC1

1. What is the procedure for a Conflict Alert or Mode C Intruder Alert?
2. What is the three letter identifier for Cincinnati-Blue Ash Airport?
3. What is the three letter designator for the aircraft company JetBlue Airways?[3]
4. Find the approach plate for Omaha (OMA) Airfield ILS RWY 32L
5. What are the SOPs for the PRAIRIE Area Wichita Arrivals?
6. What are the LOA procedures between ZKC and ZMP?
7. What is the procedure for emergency beacon code assignment?
8. What is the latitude/longitude of the MAGOO intersection?
9. What is the aircraft company designated by NKS?
10. Find the approach plate for Topeka (TOP) Municipal GPS RWY 13
11. What are the SOPs for RIVERS STL Area Departures Routed via CARDS SID?
12. What are the LOA procedures between ZKC and Oklahoma City (OKC) Tower?
13. What is the procedure for radio communications transfer?
14. What is the name of the NAVAID identified by TNP?
15. Who is the aircraft manufacturer of the A748?
16. Find the approach plate for Liberal (LBL) Municipal VOR RWY 35
17. What are the SOPs for the TRAILS Truman Coordination Procedures at Sector 42?
18. What are the LOA procedures between ZKC and Kansas City (MCI) Tower?

[3] After the first day, we changed JetBlue Airways to Air Wisconsin. The participants tended to enter JetBlue with a space between Jet and Blue when searching for the three-letter designator, but the search engine did not recognize that spelling.