A Case Study of Human Factors Evaluation in Aircraft System Certification

by

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Submitted to the System Design and Management Program in Partial Fulfillment of the Requirements for the Degree of Master of Science in Engineering and Management at the Massachusetts Institute of Technology February 2002

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ABSTRACT

A human factors evaluation was performed on a privately developed Multi-Function Display (MFD) intended for use in general aviation aircraft. The MFD was at the end of its product development process and the parent company was pursuing its flight certification with the Federal Aviation Administration. The new MFD is a large departure from the current industry design standard for these devices. The new design, it is hoped, would markedly improve pilot situational awareness and reduce the cockpit workload in general aviation aircraft.

The evaluation was performed to understand the effect that the MFD's larger display area, improved graphics, and unique pilot interfaces, would have on reducing the time it takes for a pilot to find information valuable for in-flight planning. The evaluation showed a strong positive correlation between pilots using the MFD requiring nearly twice as much time on average to retrieve desired information than pilots using only a paper VFR Sectional. Pilots utilizing the MFD to locate and report specific information averaged 19 seconds per question to complete a task. The same questions answered with a VFR Sectional only required 11 seconds per question on average. Additionally, pilots committed nearly twice as many total errors using the MFD (65% of all errors) than with the paper system (35% of all errors). The evaluation only considered tasks related to information discovery and retrieval and was not a comprehensive look at all of the MFD's known functionality. The conclusion was that poor human factors design unnecessarily encumbered detailed information retrieval.

Eight test subjects were analyzed while working with four separate flight plans to determine the cause of the disparities in both time and error and recommend ways for correction. Analysis of the human factors tradeoffs and the product development process resulted in recommendations affecting the organization, content, and structure of the MFD and its graphical displays. Primarily, the device requires an improved map interface for direct pilot interaction. Additional recommendations concerning the product development process of the company were included to improve the process and avoid similar mistakes in the future.
Dedication

For my wife and family, the love and inspiration of my life.
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1. Introduction

1.1 General Aviation Mishaps

In August of 2001, the United States General Accounting Office (GAO) reported to Congress that across the entire spectrum of aircraft, the mishap rate for all civil aircraft not flown by commercial airlines or the military is 24 times higher than the accident rate for commercial aircraft (GAO, 2001). This portion of the domestic aviation fleet is known as general aviation (GA) and accounts for three out of every four takeoffs and landings in the United States. The General Accounting Office further explained that the disparity between general aviation and commercial aircraft could be attributed to a variety of factors. Of particular note, however, is the finding that over “two-thirds of the general aviation aircrafts mishaps, both fatal and non-fatal, are caused by pilot error” (GAO, 2001). Pilot error can include mistakes related to procedure, skill, and judgment and can be both exacerbated and/or mitigated by how well pilots interact with the electronic and mechanical systems they manipulate to safely fly an aircraft.

Different segments of the general aviation community, however, have widely varying mishap rates. For example the corporate flying segment uses almost exclusively turbine aircraft and accounts for 10 percent of the total general aviation hours but only one percent of the fatal accidents. Conversely, the personal flying segment, populated by persons who fly for pleasure or personal transportation and not for business, comprised about one-third of total general aviation hours flown in 1998 but accounted for over three-quarters of the fatal accidents. The disparities are attributed to “differences in pilot experience and safety equipment installed” (GAO, 2001).

The modern aviation industry recognizes that there exists a large opportunity to compensate for both of these factors through advanced technologies that can potentially affect
both aircraft flying characteristics as well as a pilot's decision making ability. Perhaps the most significant recent technological advance to impact the pilot in the cockpit was the coming of age of the Global Positioning System (GPS) and the development of cheap, hand held devices to bring precise position information immediately to the pilot in the cockpit. Initially, this technology allowed pilots and early adopters to exactly plot their positions on paper sectionals and other plotting devices. As technology has advanced, the hand held device is giving way to fully integrated systems that can couple built-in databases of terrain maps, geography, topography, local traffic, weather and anything else that can be imagined and associated with the GPS data to provide real-time, pilot manipulated, moving maps filled with data for pilots to use as they see fit. The real challenge in today's environment is to determine the best way to gather, display, disseminate, and interact with the immense amount of data that is now at the pilots' very fingertips.

1.2 Human Factors and General Aviation

Human factors (HF) engineering attempts to understand the strengths and limitations of human beings and then apply this knowledge to the machine interfaces that we must deal with on a daily basis. Originally, human factors research examined the interactions of humans with very specific devices. It has since expanded to cover an ever-broadening scope of engineering disciplines, behavioral sciences, and human-machine interactions. Within the field of aviation, ever since Wilbur Wright chose the canard configuration for the first powered flyer because, among other reasons, he thought it was comforting to see the control surface during flight (Culick, 2001), engineers have been looking for ways to improve the way pilots, crew members, passengers, and now air traffic controllers and even ground personnel interact with aircraft and each other. The aviation human factors sciences cover everything from cushions and seat design,
to control interfaces, to cockpit crew interactions, and lately to information handling and cockpit displays.

As aircraft have become more complex, the FAA has become increasingly cognizant of the need to monitor and even regulate the ways in which aircraft meet certain human factors considerations. The FAA already tightly controls the criteria for determining an aircraft’s suitability for flight through a comprehensive and meticulous certification process. Any aircraft or aircraft system slated for flight in US airspace must demonstrate compliance with criteria as established by the FAA before it is permitted to take to the skies. As aircraft are improved, systems are upgraded, or new systems are developed, the same flight certification process must be completed in whole or in part before the new or changed elements may be incorporated, let alone widely sold, for use in domestic aircraft. However, the dynamic and fast paced nature of technological evolution has made it extremely difficult for FAA regulations to keep pace. Particularly with regard to human factors, the result for today’s manufacturers is a myriad of requirements and guidelines from multiple government and private agencies that are not only challenging to identify but can also be even harder to implement wisely. Indeed, FAA regulations rarely directly identify requirements as “human factors” related and a developer needs to thoroughly review a multitude of sources to determine their product’s level of compliance.

In recent years, there has been independent effort to consolidate the human factors guidelines from all of the sources into a single working reference. The Human Factors Design Guide published by the US Department of Transportation and most recently updated in April 2001 makes a Herculean effort to review all of the current and relevant material regarding human factors best practices and requirements and then summarize this information in a user friendly
format (Department of Transportation, 2001). The most recently developed and most often requested update concerns the issue of computer-human interfaces. As may be suspected, the rapid technological advancements in the area of computer software, graphical interfaces, and associated hardware improvements have enabled an enormous wealth of information to be pumped into the cockpit from various sources, in different formats, and with a wide range of usability and applicability issues associated with it. The commercial airlines have always had high-tech cockpits and the first electronic display units were introduced to this industry as early as the 1970s. However, the presence of electronic display units, now evolved into what is now known as multifunction displays (MFDs), have increased their functionality while becoming relatively affordable and thus enabling them to become more common in the general aviation market as well.

1.3 Multifunction Displays and Human Factor Engineering

Multifunction displays serve a variety of functions. Remembering that the most common cause of mishaps for general aviation aircraft is related pilot experience and safety equipment installed on a particular aircraft, the focus of many modern MFDs is to enhance the pilot’s understanding of his environment. MFDs receive information from a variety of sources and then will attempt to layer that information onto a single display unit. For example, most current MFDs receive position information supplied by the GPS satellite network and then map that information onto an onboard database of information that can include such things as geo-political boundaries, controlled or special use airspace boundaries, VFR airways, airport positions, obstacles and other fixed items that may be of interest to pilots. More advanced MFDs can also overlay local generated RADAR returns and traffic and weather information. The intent is to keep a pilot’s focus on one display that has all information that will be useful during a flight. By
consolidating and centralizing the information, MFDs hope to improve a pilot's situational awareness (SA) of their environment while simultaneously reducing their workload. Instead of having to learn how to read and interact with several different pieces of equipment that may gather useful information, an MFD enables a pilot to see and manipulate all of that same information through a single display. Typically, the information is "layered" on a display screen that allows a pilot to add or remove items they are interested in seeing. For example, a pilot may wish to see controlled airspace information and local obstacles but perhaps not at the same time on the same display. The ability to customize the display to fit a user's needs is critical as the potential information density typically far exceeds the viewing area available on an MFD display. An MFD is then continually updated with new GPS position and other information to provide a real time snapshot of the pilot's environment.

As may be expected, developers have put forth a myriad of formats to present the information on their MFD and an equal number of methods for a pilot to interface with the device. Modern MFDs provide operators with control through pilot initiated filtering of information as well control of the level of detail that will be seen next to the selected information. It is not hard to imagine that as computing power and display capabilities improve, the volume of information that can be presented can quickly outpace the pilot's ability to process and understand it. An important aspect of any human factors consideration of an MFD is to understand the usability of the device on this most basic level. It is not difficult through poor design for the information to become muddled and confusing as well as extremely difficult to manipulate and configure. In the worst case, information overload, a poor display, or difficult user interface can have exactly the opposite effect the MFD is intended to have. A poor display can actually decrease pilot situational awareness while increasing their workload. As developers
attempt to address the general aviation mishap rate that is dominated by pilot error as the primary cause, it is important that the information solutions do not add to the problem by permitting the displayed information or the pilot's ability to interface with the display device to become compromised.

The technology explosion and myriad of design solutions for information presentation have led to an unquestioned need for standardization as well as a clear understanding of human factors considerations when designing MFDs. Not surprisingly, the aviation industry has responded with a wealth of new research into exactly these fields. In September 2001, the Department of Transportation released a study based on a review of research and literature specific to the design of aircraft multi-function displays (Department of Transportation, 2001). The report, aptly named Human Factors Design Guidelines for Multifunction Displays, systematically reports on the various aspects of MFD design for usability and the recommended best practices for designers therein. The report identifies what works for pilots and other end-users from a strictly functional perspective. The guide does not cite FAA certification requirements in its best practices but nonetheless it is possible to combine the guidance in this report with the FAA and other government regulations identified in the Human Factors Design Guide noted earlier to draw a more complete picture. What has become very clear after a lengthy literature review is that while human factors consideration must be imbedded in all good engineering, there exists no comprehensive list of absolute HF requirements. Moreover, it is more likely that it is impossible to even create one. Human factors engineering is not an exact science per se, but more an analysis of tradeoffs. It is not realistic to believe a single checklist could provide the precise guidance a designer needs to build the perfectly designed system for human factors considerations. This point is raised now to make it clear that ultimately it will be
the user who will be the final arbiter of whether a product is really “useful” or not. Ed Crawley, Department Head of Aeronautics and Astronautics at the Massachusetts Institute of Technology, identifies a component he labels “elegance” to describe truly exceptional systems engineering (Crawley, 2000). An elegant design is one that appeals on all levels of the users needs, aesthetic to practical. It is my belief that the realm of human factors engineering is the one area where engineers attempt to directly handle the issue of elegance. The trade-offs that are evaluated for human factors speak directly to the elegance of the design as much as to its real usefulness to a user.

1.4 Purpose

Human factors considerations should be imbedded in all aspects of the product development process. Often, however, human factors considerations are the last thing on a developer’s mind. Particularly for the first version of a product line, internal or external deadlines or simple monetary issues can often drive the developer’s priorities. Human factors concerns are often not carefully analyzed or understood until a problem arises requiring a design change to achieve at least the minimal usability requirement. In the following thesis, I will examine the Avidyne Corporation’s newest MFD for general aviation aircraft and their associated product development process. The context of the examination will be the human factors requirements for MFDs in the general aviation market. The purpose of the final evaluation is to understand the human factors tradeoffs Avidyne needs to consider when designing an MFD, the strengths and/or weaknesses of their design effort through an analysis of their EX5000C MFD, and to assess the results of the analysis as an impact on their product development process. More specifically, The Avidyne Corporation in Lincoln, Massachusetts has developed the EX5000 MFD for use in general aviation aircraft and understands the implicit
need for a human factors analysis of their new component. Avidyne has voluntarily decided to initiate an HF test and evaluation program for the MFD to support it in its FAA certification as well as to enhance its market appeal. This thesis will evaluate, analyze, and capture the relative elegance of the EX5000 for use by the general aviation community and thereby assess the relative success of the human factors aspects of the Avidyne product development process.

2. Background

2.1 General Aviation Navigation

General aviation pilots are as varied in their reasons for flying as they are in their means of figuring out the safest and fastest way to get around. GA pilots can fly using Instrument Flight Rules (IFR) or Visual Flight Rules (VFR). All pilots learn to fly VFR and with experience and practice, some will move on to earn an instrument rating. VFR flight requires the pilot to have constant reference to the actual horizon with the pilot’s eyes. To fly IFR requires the pilot to have formal instrument flight training that may then lead to an Instrument Pilot Rating. Instrument rated pilots have learned how to fly and navigate their aircraft using only cockpit instruments and without requiring visual reference to the outside environment. The instrument rated pilot can take their aircraft into the clouds so to speak and then navigate and fly with only reference to the instruments in their aircraft. A pilot flying IFR is under constant supervision and control from ground based air traffic controllers and the pilot will supplement his or her navigation with special IFR charts and other devices. For the VFR pilot, however, aircraft navigation is handled through a spectrum of very simple to very high-tech devices.

On the low technology side, many pilots will navigate in much the same way a person navigates in their car. In fact, some will use roads or other known landmarks as their primary
references to move from point A to B. Of course, the advantage of flying is that a person can travel greater distances much faster than in a car so it is not difficult to rapidly out-fly a pilot’s internal list of known landmarks. Most pilots will then turn to the FAA issued pilot’s VFR Sectional. The VFR Sectional, or simply “Sectional” as it is referred to by pilots, is essentially a pilot friendly map. It can include much of the same information available to in a normal road atlas, but it magnifies the information of importance to a pilot. Obvious things such as airfields, restricted airspace, in flight obstacles and other landmarks that will be visible from the sky that may never be seen from a car are readily visible on a sectional. The legend on a VFR Sectional contains over 110 different types of symbology. All VFR pilots will receive some training on the use of a sectional prior to receiving their private pilot’s license. With a sectional in hand, any pilot should be able to execute a VFR flight even into unknown areas. A section of a VFR sectional from the Daytona Beach, FL area is shown in Figure 2.1 below.

Figure 2.1: Sample VFR Sectional
The next level of technology for VFR navigation is the use of hand-held GPS devices. The market is flooded with these handheld computers and many have become quite adept at presenting pertinent and complex information in what is typically a very small display window. Common problems with handheld devices are the small viewing area coupled with the deeply layered information interfaces that require significant mental effort to use for more than the simplest of tasks. Nonetheless, the information these types of devices provide can be quite detailed and they have attracted a supportive and devoted customer base. For the most common GA flying, the personal non-business flyer, a hand-held GPS seems a reasonable financial investment for the level of usability they provide. A popular model, the GPS III Pilot manufactured by the Garmin Corporation is shown in Figure 2.2 below.

Figure 2.2: Hand Held GPS- Garmin GPS III Pilot

Figure 2.2 is representative of the most common kind of hand held GPS receiver in use in the GA market today.

For high technology integrated systems, the GA community also uses multi-function displays. Within the GA market, MFDs have typically been reserved for expensive corporate or business type aircraft. These aircraft can bury the historically high cost of an MFD in the overall cost of the aircraft without too much difficulty. Moreover, these aircraft typically travel greater distances more often and into dense population areas where the extra MFD functionality seems
better suited. However, there is a push in the avionics industry to bring the cost of the high-tech MFDs down into the realm of the smaller GA aircraft and allow users to leverage the full advantages of an integrated system. New GA aircraft manufacturers across the entire range of aircraft are building MFDs into their designs from the beginning. Avionics manufactures like Garmin, Barcoview, Honeywell, Bendix, Avionics West, and Avidyne among others are all competing for this new market. MFDs differ from VFR Sectionals and hand-held GPS devices on a number of levels. Perhaps the most obvious is that they are integrated with the rest of the aircraft avionics and instrumentation suite. An MFD can be used to provide map information similar to a VFR sectional coupled with GPS like a hand-held device, but they are also used for engine monitoring and diagnostics, providing an electronic checklist, as well as integrating weather, radar, and traffic information from multiple sources into a single display. MFDs will attempt to consolidate all (or as much as possible) of the digital information in a cockpit from multiple sources into a single display unit. A single point of information retrieval, it is hoped, will then enhance a pilot’s situational awareness and reduce their workload.

### 2.2 Avidyne FlightMax EX5000

The Avidyne Corporation of Lincoln, Massachusetts has spent the past two years developing the EX5000C MFD for the general aviation market. Introduced formally to the general aviation community at the annual Aircraft Owners and Pilots Association (AOPA) Exposition in November of 2001, the EX5000 is the Avidyne Corporation’s attempt to raise the industry standard for MFDs well above current industry products. Originally conceived as a follow-up to their Flight Max line of MFDs, with the key feature improvement being the larger glass display area, the EX5000 has gone farther and represents a large step from the company’s earlier products.
Simply put, the EX5000 MFD is an integrated electronic display that, among other things, combines the functions of a real-time moving map; electronic checklists, traffic and weather advisories, and flight plans are overlaid into a single display. A quick survey of multi-function display devices in the General Aviation (GA) market reveals a market saturated with devices purporting to have the same basic functionality as the Avidyne model. The Avidyne MFD becomes unique and quickly distinguishable from any other model on the market by the sheer size of its display. The Avidyne MFD liquid crystal display (LCD) measures a relatively enormous 6.25 inches by 8.5 inches (10.4 inch diagonal) for a total viewing area of over 53 square inches. Current models generally vary from around a three-inch diagonal display up to over six inches of diagonal display. Only one other model matches the EX5000 in display size but lacks the matching screen resolution, thus making it appear less sophisticated.

Since its debut at the AOPA Exposition, Avidyne has contracted with several aircraft manufactures to integrate the EX5000 into their product lines. Most notably, the first widespread use of the EX5000C will be in the all new Cirrus SR22 and will be back-fitted into the older model Cirrus SR20 GA aircraft (Figure 2.3). Cirrus Corporation aircraft will be the first widespread users of the EX5000 (Figure 2.4) so it is important to Avidyne that the MFD is seen as a resounding success with their pilots. The Cirrus philosophy on GA as described on their corporate home page states, “A Cirrus is a personal aircraft that can be used for more than recreation, it represents a reasonable transportation alternative.” In terms of the GA aircraft community, Cirrus seems to be trying to fill in the gap between the weekend flyer and the business flyer. It seems clear that at least in the near term the EX5000C will have demands that fall across a broad spectrum of GA needs.
2.3 EX5000 Operation and Arrangement

Before any work can be accomplished evaluating the EX5000, it is important to understand its basic layout, functional interfaces, and general capabilities. For purposes of this thesis, it is not critical to have a detailed understanding of all of the available functionality of the EX5000. The EX5000 allows for a multitude of pilot controlled settings and inputs that will not
be dealt with in this evaluation. For a comprehensive explanation of the EX5000 an interested party should review the Pilot’s Guide in its entirety (FlightMax EX5000C, 2001).

The EX5000 MFD consists of a metal bezel framing a liquid crystal display (LCD) that measures 6.25 inches tall by 8.5 inches wide (Figure 2.5 below).

Integrated into the left and right sides of the metal frame are five backlit push buttons used for making pilot inputs (Item 1, Figure 2.5). The bottom edge of the metal frame has two raster-type knobs located at the left and right bottom corners respectively (Item 2, Figure 2.5). The Avidyne logo appears across the top edge.

The box functions are organized around five core “page” options. These core pages represent the highest level of the function selections and are referred to as the Map, Trip, Nearest, Checklist, and Setup pages. The core pages are identified on the LCD display in a line along the bottom left corner of the display (Item 3, Figure 2.5) with the labels “Map”, “Trip”, “Nrst”, “Chklst”, and “Setup”. The different core pages can be selected by turning the lower left
raster knob and the current core page will have its identifier backlit turquoise. On each core page (and subsequent lower page levels) the purpose of the five buttons along each side of the MFD is displayed inboard of the button in its corresponding function boxes (Item 4, Figure 2.5). The function boxes will describe a new page that will be displayed or the action that will occur when the respective button is depressed. At times, a button may not have a function assigned to it in which case there will be no function box on the display screen near it.

2.3.1 EX5000 Setup Page

Turning the lower left raster knob all the way to the right will take you to the Setup core page (Figure 2.6). From the Setup page a user can, among other things perform maintenance tests as well as configure the MFD to the type of aircraft. On the top right side of the page are three functions labeled from top to bottom “Airport Filter”, “Declutter Setup”, and “Data Block Edit”, respectively. Pressing the button immediately to the right of the function box will bring the user to the corresponding page.

![Figure 2.6: Setup Page](image)
The Airport Filter page (Figure 2.7) allows a user to configure what types of airfield will be displayed on the core “Map” page. A user can filter airport by type (“Towered, Non-Towered), surface (“Hard”, “Soft”, “Water”) and runway length. The various fields on the page can be selected using the arrows buttons or the right raster knob. Changes to a field are made using the “Change Value” function button. Each push will advance the user through a change option. There is no display of all available options visible at any time.

![Airport Filter Page](image)

**Figure 2.7: Airport Filter Page**

The Declutter Setup page (Figure 2.8) allows a user to configure the type and manner in which certain map symbology will be displayed. There are 13 categories of information that a user can manipulate. Again the right raster can be used to move rapidly through rows or the arrow key functions serve the same purpose. The type of map information that can be manipulated is shown in the third column. Only the first two columns can be changed. The first column is titled “Display” and has three options. A line item that has its display set to “Auto” will appear on the map based on the relative amount of clutter already on the map and the priority the computer displays to this particular set of information. The line item information may or may not be
displayed depending on these particular declutter settings implemented by the user and the MFD’s preset priorities. The determination is automatic, hence the name. The second Display option is “On”. This means that the particular line item will appear regardless of clutter. It may be overwritten based again on preset computer priorities but in most cases, the information should be visible. The final setting is “Off” in which case the line item will not be displayed on the map at all.

![Figure 2.8: Declutter Setup Page](image)

The second column is titled “Label”. When the Label box is check marked, alphanumeric information will appear near the map symbology as amplifying information. The exact information is unknown until the user goes back to the map page to see the changes. For example, selecting Label check marked for Class B/C airspace will result in the floor and ceiling restrictions for the controlled airspace to appear near or within the airspace boundaries. The Fourth column describes the range scales at which the desired information will be displayed. A cyan filled bubble means that the corresponding information will be displayed at that
particular range scale on the Map core page. The dashed vertical line going through all rows shows the current range scale selected on the Map core page.

The “Data Block Edit” page (Figure 2.9) allows the user to configure the nature of the information that may be displayed in the data blocks visible in the top corners of the core “Map” page. Available Data blocks can be set to display the range, bearing and estimated time enroute (ETE) to the nearest waypoint, range and bearing to the next waypoint, range and bearing to the nearest airport, local time, Latitude and Longitude, Universal Time Clock, ground speed, altitude and indicated airspeed. Several of these options will take two of the six lines in a data block. Since only 12 lines are available (6 per data block) not all of the possible information can be selected for display at one time. There is no default setting for the data blocks.

![Data Block Edit Page](image)

*Figure 2.9: Data Block Edit Page*

Other functions may be accessed from this page but will not be discussed in this paper.
2.3.2 EX5000 Checklist Page

The Checklist core page is labeled “Chklst” on the main display and is sequentially located next to the “Setup” core page. Selection of this page will bring the user to an interactive electronic checklist. The checklists are organized by normal procedures and emergency procedures. The checklists are aircraft unique and also contain performance data for the aircraft.

2.3.3 EX5000 Nearest Page

The Nearest page is labeled “Nrst” on the main display and is in the third position sequentially among the five core pages (Figure 2.10). Rotation of the left raster to this position will bring a core page titled “Nearest Airports” to the display. Airport information is arranged in five columns titled “ID”, “BRG”, “NM”, “FREQ”, “NAME”, which corresponds to the airport three or four letter unique airport identifier, bearing from the aircraft present position, distance in nautical miles to the airport from the aircraft present position, the frequency of the primary control frequency (Note: the frequency could be a common traffic advisory (CTAF) or universal communication frequency (UNICOM) in cases of non-tower controlled airports), and the full name of the airport respectively. Airport rows can be scrolled through using either the arrow push buttons or the right raster knob.
Selection of the “Airport Info” push button will bring up a more detailed page of information on the currently selected airport row (Figure 2.11).

Referring back to Figure 2.10, the top function key on the left side has a primary label of “Type” and a subtitle with a green outline that says “AIRPORT”. The green outlined “AIRPORT” indicates...
the current type of nearest information being displayed. Selection of the "Type" push button will move the display through a series of pages each with different nearest information. The green outlined subtitle will change to the current information type being displayed. A page is dedicated to nearest VOR navigation aids, obstacles, intersections, and non-directional beacons. Each of these pages has the same range, bearing, frequency (not the obstacle or intersection page), and name (not obstacle) columns visible. The obstacle page has a column for the height of the nearest obstacle as well. No further amplifying information is available to the user on these subsequent pages.

2.3.4 EX5000 Trip Page

Rotating the left raster to highlight "Trip" in the second position along the bottom left corner of the primary display will bring a core page similar in appearance to Figure 2.12.

![Figure 2.12: Trip Page](image)

This page will display the aircraft’s current position relative to the active flight plan. The flight plan itself is entered from a separate device. In the case of the Cirrus SR22, the device is a Garmin GNS 430 (Figure 2.13). The GNS 430 also provides the real time GPS data the MFD
needs to orient its own map and is also where a pilot will input a desired flight plan for display on the EX5000. On a separate note, it is also an excellent example of a small screen MFD-like device available to the GA market.

Figure 2.13: Garmin GNS 430- Panel Flight Management System

Referring again to Figure 2.12, the Trip core page provides the user with information relative to the aircraft’s current position in the flight plan. Multiple waypoints may be entered for a proposed flight path that will then appear on the Trip page. In Figure 2.12, three waypoints were entered and the first one had already been reached at the time of the screen capture. Once a waypoint is reached, the MFD will drop the leg information from the display until upon completion of the flight there are no legs displayed on the page. The MFD highlights in magenta data relating to the current leg of the flight and all subsequent leg data is displayed in white. Each waypoint also includes information regarding its current bearing and, for the active leg, the current distance from the aircraft, ETE and estimated time of arrival (ETA) in local time. The distance, ETE and ETA listed on subsequent legs is the cumulative value to get to that point. Additionally, a desired track (DTK) is listed to reach each waypoint and a course deviation indicator (CDI) is included at the top center of the screen to show the range of deviation from the desired track. The current track is listed in the top left corner labeled “TRK” and located just beneath the current GPS computed groundspeed labeled (GS). The top right corner contains local and UTC time. None of the fields in the top corners can be altered. Airport information
about the final destination airfield is available using the right function key labeled with the
destination airfield identifier and the word “Info”. Intermediate airfield information cannot be
accessed through this page.

2.3.5 EX5000 Map Page

The “Map” page is visible in the first position along the bottom left corner of the primary
display. Highlighting this core page will result in a map display that is the real heart of the
MFD. Earlier descriptions of the other core pages were all centered on enhancing the user’s
understanding of what is displayed on the map page. Figure 2.14 is sample of a map page with a
flight plan overlay that was also used to explain map features to the test subjects described later
in the thesis. Figure 2.14 is Flight Plan A from the test plan.

Figure 2.14: Map Page- Flight Plan A
The map page contains a wealth of information. Like the VFR sectional, topographic elevations are depicted with color with a supporting legend under the right data block. Also similar to a sectional, airport locations with some distinction by type, controlled and special use airspace boundaries, obstacles and their elevations, runway orientation, controlled airspace altitude restrictions, and navigation aids are all visible. Additionally, an aircraft centered compass rose referenced to Magnetic North is visible that is also associated with the current map range. The current map scale is visible near the one o’clock position on the compass rose and can be increased or decreased by twisting the right raster knob. The MFD map can also declutter some of the map symbology by pressing the declutter push button. The small triangle beneath the word “Declutter” indicates the current level of declutter the map is showing. The triangle will become more and more empty with each push of the button and the removal of another type of map symbology. An empty triangle will leave a display showing only topographic and political boundary information. There is no indication on the screen of what data exactly drops off with each push of the button other than a user noticing an item that was previously visible now being missing from the display. Selection of the “BaseMap” push button will cause topographic and political features to drop off. Much like the “Declutter” triangle, the cube beneath the word “BaseMap” will become less filled with each push of the button. One push causes all topographic information to disappear and the next causes all political and water boundaries to drop off. A third push resets the map to the full display configuration.

The map orientation is set using the “View” push button. The green outlined subtitle indicates the current map view and a small triangle also appears near the top of the display to indicate the map orientation. Users can select the “Heading/Track” or a “North” up views. In the Track/Heading up view the triangle will have either a “T” or “H” indicating track or heading
view respectively. In this view the map is oriented with the current aircraft heading or track being fixed to the 12:00 position. This causes the aircraft symbol to always point to the 12:00 position and the map appears to update or spin beneath the aircraft symbol. The heading/track up view can be further modified with the map being centered around the aircraft or in the “Forward” view where the aircraft is offset to near the bottom most edge of the screen and the map displays only the view forward of the aircraft. The North up view keeps the map oriented to true North while the compass rose always points to magnetic north. The aircraft symbol points in the direction of the aircraft heading and the map updates as the aircraft moves across it. The maps position over the land cannot be moved off of the aircraft centered or forward view positions. In other words, the map cannot be scrolled away from the aircraft position to see something that may not appear within the current range scale. Additionally, there is no ability to select from this core page specific information visible on the map for amplifying information. Any amplifying information desired by the pilot will necessarily come from other MFD pages, VFR Sectionals or other cockpit resources.

3. Experimental Study

3.1 Scope

“Pilots... are highly trained and able people. Their behavior is organized and goal-directed, and they add knowledge to the information on an interface in two main cognitive activities; understanding what is happening, and working out what to do about it” (Bainbridge, 1999). The pilot’s ability to understand what information is available to him and how to best retrieve the desired information is one of the first questions that must be answered when addressing the human factors issues of any display device.
It is not difficult to envision the EX5000 being used by pilots for purposes ranging from local sight seeing to long-range travel. The EX5000’s first customers will be flying the Cirrus SR-20/SR-22 aircraft and the Cirrus vision for its aircraft appears to be moving toward covering an entire spectrum of GA missions. At one end of the spectrum are the weekend flyers. These pilots may turn an eye to the weather, hop in their aircraft and fly VFR for their own recreational purposes. At the other end of the spectrum is the business flyer that regularly flies exact routes, greater distances, primarily under IFR, for business related purposes. Across the spectrum, the pilots will likely employ the EX5000C for some very similar purposes. At a minimum, all pilots flying VFR will likely try to use the device to identify airspace restrictions and to gather airport and other information along their proposed route of flight or proposed flying area. The EX5000C is after all purported to first and foremost promote a pilot’s situational awareness of their flight environment.

A test was designed to evaluate a potential GA pilot’s ability to understand the display capabilities and user requirements for information retrieval using the Avidyne EX5000 MFD. The test evaluated a pilot’s ability to find, determine, or interpret information that would be useful on a proposed VFR flight plan. A direct comparison was made for information retrieval from the MFD versus information retrieval using only a VFR Sectional. The VFR Sectional is used as the basis for the comparison as it is assumed to be commonly familiar with all GA pilots and also represents the realistic and most likely alternative to navigation in the aircraft in the event of the failure or inadequacy of the MFD. The questions were designed to be simple, straightforward and pertinent. The test uses a snapshot from the MFD to answer questions relating to all areas of the flight plan. The lack or presence of information in the particular MFD snapshots used during the test is not necessarily indicative of what the map would look like for a
pilot actually flying the flight plan. In flight, the map page updates rapidly and the display is relative to the aircraft position. This test is best suited for evaluating the elegance of the means for information retrieval, the quality of the information available, and the pilot’s ability to use the MFD in lieu of a sectional. Results of the evaluation will be used to support or contrast Avidyne’s belief that the EX5000C MFD will promote pilot situational awareness and reduce workload. It should be noted that the Avidyne Corporation does not advocate using the MFD as the primary means of navigation nor does it possess the FAA certification to be employed in that capacity.

3.2 Description Of The Test Device

The human factors evaluation of the EX5000 MFD was originally conceived as an in-flight evaluation. Although never a serious option, it is obvious as the best configuration for performing a human factors evaluation. The secondary and primary plan was designed to take advantage of a static cockpit simulator being built by Avidyne to mirror as closely as possible as Cirrus SR22 cockpit. Eventually, time and technical difficulties prevented the cockpit from being functional and a third option to evaluate the MFD as a stand-alone device was pursued.

The evaluation of the EX5000C was accomplished using a stand-alone MFD receiving simulated GPS data from a Garmin GPS III Pilot hand held device (Figure 2.2). An EX5000C Version 5.2.0, Build 11 was used for the evaluation. The Jeppeson navigation data used by the EX5000 was valid through 27 Dec 2001. The MFD was set upon a tabletop and raised to near eye level with a cardboard box. Test subjects were able to adjust their seat to their desired viewing height as necessary. The EX5000C was not secured to the box or the table but the test subjects could manipulate single handedly all interfaces without the box sliding around. The evaluator sat to the right of the MFD and test subject and recorded data by hand on the desktop.
Events were timed manually using a computer clock and noting the current time in minutes and seconds for data recording. Test subjects were evaluated in a private area free from external distractions during the test and evaluation period.

As a dynamic simulation using the MFD was not possible, the proposed flight plans were inputted into the MFD and the aircraft position was centered at the center of the flight plan route. The same flight plans were marked on a VFR Sectional and the waypoints routes of flight were clearly marked without marking out information required during the test.

### 3.3 Flight Plans and Sectionals

The flight plans referenced throughout this test plan are characterized as having two legs with three waypoints. The flight plans were selected to represent a variety of different locations with diverse geographic and geo-political backgrounds. The waypoints are summarized below and associated graphics of the flight plans as seen by the test subjects on the MFD can be found in Appendix A.

**Flight Plan A-** Olympia (KOLM)- Seattle-Tacoma (KSEA)- Snohomish County (KPAE)

**Flight Plan B-** Deland Municipal (KDED)-Orlando Sanford (KSFB)-Ormond Beach (KOMN)

**Flight Plan C-** Herlong Airport (KHEG)-Jacksonville International (KJAX)-Fernandina Beach (55J)

**Flight Plan D-** Orlando Country (X04)- Kissimmee Muni. (KISM)- Merritt Island (KCOI)

**Flight Plan E-** Portland International (KPDX)- Portland Hillsboro (KHO)- Portland Troutdale (KTTD)
### 3.4 Counterbalancing

Counterbalancing of the experiment to account for learning, fatigue, and other order effects was implemented according to the schedule in Figure 3.1. Flight Plan A (Figure 2.14) was employed first as a common training tool for all participants in the experiment. Flight Plans B, C, D, and E were then executed in order. Execution of each flight plan was divided into two parts. In each part, the subject was required to determine his/her answers using either the MFD or VFR sectional exclusively. To complete the second half of the flight plan, subjects answered questions using the previously unused resource. The order of the subject evaluations and the order the resources were used are shown in Figure 3.1.

<table>
<thead>
<tr>
<th>Flight Plan</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
</tr>
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<tbody>
<tr>
<td>B</td>
<td>B-MFD Sect</td>
<td>B- Sect MFD</td>
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<td>E-Sect MFD</td>
</tr>
</tbody>
</table>

Figure 3.1: Counterbalancing Matrix

### 3.5 Subject Pool

As this test in no way evaluated the effect of the MFD on actual flying metrics, seven rated pilots and one rated navigator were utilized as test subjects. The average age of the subjects was 35 and consisted of seven males and 1 female participant. All pilots had fixed wing experience. Three of the subjects had primarily military flight experience with one subject having nearly all military helicopter time. The average flight time of the subjects was just over 1100 hours with an average of 300 hours instrument time per test subject. Only one subject was
not instrument rated. Additionally, all of the test subjects reported having experience with GPS navigation devices in the past and all but one had used an MFD in their aircraft experience. When asked to rate their personal comfort level using computers on a scale from 1 to 5, five being the most comfortable, the average score was 4.3.

The subject group covered well, if but thinly, the scope of general aviation pilot targeted by the Avidyne MFD. Generally speaking, they were well-experienced VFR pilots that are comfortable with GPS navigation and its associated systems.

3.6 Subject Instructions and Procedures

Subjects were each provided the following formation regarding the purpose of the study: “The purpose of this experiment is to evaluate the Avidyne FlightMax EX5000C MFD for information retrieval on proposed VFR flight plans. The evaluation will attempt to characterize the ease of retrieving information, the value of the information available, and other general usability issues for general aviation pilots and aircraft. This experiment will consist of four separate static flight plan presentations displayed on a fully functional EX5000C MFD and on the associated VFR Sectional. You will be asked to perform a series of tasks while flying a simple flight plan along pre-planned flight parameters. The entire experiment should take approximately 1.5 to 2 hours.”

The test was performed using “crib sheets” for the evaluator for guidance and data collection. A copy of the actual crib sheets for each of the flight plans is included in Appendix B. The remaining steps in the evaluation are listed below.

3.6.1 Non-Avidyne employees read the consent form and non-disclosure agreement and signed their name.

3.6.2 Subject completed the pilot background and experience questionnaire.
3.6.3 Subject was familiarized with MFD and its capabilities and modes of operations. Flight Plan A was presented on the MFD and a VFR sectional and the user was asked to perform a unique series of tasks with both the MFD and the VFR Sectional that will be indicative of the upcoming evaluation period. The evaluation did not proceed to the next step until the subject declared himself ready.

3.6.4 Subject was presented with a VFR sectional with the waypoints and desired track already labeled. Subject was allowed to review the flight plan on the MFD and sectional until they declared themselves comfortable with flight plan. Subject data was then collected while the subject was viewing Flight Plan B and performing tasks as directed by tester. The first half of the questions from each flight plan was answered using either the MFD or VFR Sectional exclusively. The second half of the questions was answered utilizing only the second unused resource. The sequence is prescribed in the counterbalancing matrix.

3.6.5 Subject completed modified Cooper-Harper Evaluations specifically relating to Flight Plan B for information discovery evaluation.

3.6.6 Subject was presented with a VFR sectional with the waypoints and desired track already labeled. Subject was allowed to review the flight plan on the MFD and sectional until they declared themselves comfortable with flight plan. Subject data was then collected while the subject was viewing Flight Plan C and performing tasks as directed by tester. The first half of the questions for each flight plan was answered using either the MFD or VFR Sectional exclusively. The second half of the questions was answered utilizing only the second unused resource. The sequence is prescribed in the counterbalancing matrix.
3.6.7 Subject completes modified Cooper-Harper Evaluations specifically relating to Flight Plan C for workload evaluation.

3.6.8 Subject completes subjective questionnaire part I (questions relating specifically to Flight Plans B and C).

3.6.9 Steps 3.5.4 through 3.5.7 were repeated using flight plans D and E respectively.

3.6.10 Subject completes subjective questionnaire part II (questions relating specifically to Flight Plan E).

3.7 Flight Plans and Data Recording

Flight plans were designed to evaluate the MFD and Sectional in a variety of flight environments. High-density airport areas are found in Flight Plan A, Flight Plan B and Flight Plan D. More moderate airport environments are found Flight Plan C and Flight Plan E. A quick look to Appendix A shows how a test subject would first see the flight plan prior to beginning that portion of the evaluation. Because it was expected that due to limited experience test subjects would stay in the aircraft centered view, (switching to a “Forward” view will place the aircraft near the bottom of the display screen and display predominantly the view “forward” of the aircraft), the flight plans were designed so that the first two legs could be seen almost entirely on a 20nm range scale. Often the proposed alternate would not be visible on the 20nm scale and Flight Plan A was intentionally oversized to show subjects how to find information “off the map” so to speak. The 20nm range scale was chosen as the basis for the decision because at this range scale the MFD most closely approximates the range on a VFR Sectional (≈ 7 nm/inch on a sectional versus ≈ 6.5nm/inch at 20nm range scale on the MFD). The types questions asked during each flight plan were consistent across all five of the flight plans.
Each question queried the subject for information that would normally be used over the course of a simple VFR flight plan. There were no “trick” questions or attempts to lead the subjects to a wrong answer. Questions were consistent in style and type across all of the flight plans. Additionally, questions were asked in a manner to mimic how another pilot or air traffic controller may ask them. The time to complete each event (referred to as “Event Times”) was then analyzed to reveal differences in the use of one device over another. Event start times were recorded after a question was read in its entirety. Event End times were recorded when the test subject returned their answer (Note: Subjects were not required to report the units of measure for their answers). The “event time” discussed in this thesis is the difference between the recorded event start and event end times. To be clear, event times do not include the time it took to read the questions. Subjects who later discovered their errors were not allowed to change their answers nor was a new event time recorded. The following sections describe the procedure followed during each flight plan, including and the exact questions and protocols for each flight plan.

3.7.1 Flight Plan A (Familiarization Flight)
1. Explain to the subject that during the first flight plan any questions regarding the use of the MFD or the VFR Sectional can be answered by the evaluator without any attempt at evasion. The first flight plan is intended to familiarize the subject with all of the functionality of the EX5000c and re-familiarize as necessary on the use of a VFR sectional. During the formal evaluation portion of the test, similar type questions may not be answered.
2. Direct user to the “Setup” page. Explain general functions available on this page and direct user to select the “Data Block Edit” function. Show user how to manipulate the data blocks. Ensure the data blocks are returned to the settings shown in Figure 3.2.

**Default Data Block Settings**

| TO WPT + ETE | LAT/LON |
| TO WPT + ETE | LAT/LON |
| NEXT WPT     | ALT     |
| NEXT WPT     | TAS     |
| NRST APRT    | GROUND SPEED |
| NRST APRT    | LOCAL TIME |

Figure 3.2: Default Data Block Settings

3. Direct the user to return to the core “Setup” page and explain in detail the Airport Filter and Declutter settings pages accessible from here. “Airport Filter Setup” and “Declutter Setup” pages will be configured as was seen earlier in Figure 2.7 and Figure 2.8 respectively.

4. Direct User to select the “Chklst” core page and describe basic functionality of the page. Inform subject that the checklist functions will not be used during the evaluations.

5. Direct the user to the “Trip” core page and explain the functions and features on this page.

6. Direct the user to the “Nrst” core page and explain the nearest Airport/Navaid/Obstacles/etc. functions, features, and options on this page.

7. Direct the user to the “Map” core page and ensure the user becomes familiar with all of the map features available. Be sure to describe all items, icons, and functions on the page.
8. Brief the subject on the upcoming proposed flight plans. All flights are planned as VFR flights. The aircraft will be have a proposed airspeed of 100 Kts with negligible wind and will be flying at 1500ft AGL as appropriate. The test subject is allowed to have paper and something to write on and nothing else during the evaluation period. Ask subject to answer the following questions using only the map or MFD as prescribed in the counter-balancing matrix.

9. **Flight Plan A Task List**

1. What is the Tower Frequency at Olympia Airport (KOLM)?
2. What type of special use airspace is located immediately southeast of the first leg of flight in the vicinity of Gray Army Airfield (KGRF)?
3. What is the floor height of the Class B airspace over Gray AAF (KGRF)?
4. What is the general runway orientation at Seattle-Tacoma International Airport (KSEA)?
5. What is the elevation of the runway at Seattle-Tacoma International Airport (KSEA)?
6. How far is Renton Municipal Airport (KRNT) from Seattle-Tacoma International Airport?
7. What is the length of the first leg of flight from Seattle-Tacoma International (KSEA) to Snohomish County Airport (KPAE)?
8. What is the frequency of the Renton NDB?
9. What is the height of the tallest obstacle within 10 nm of the proposed track from Seattle-Tacoma International Airport (KSEA) to Snohomish County (Paine Field) Airport (KPAE)?
Switch to either MFD or VFR Sectional as appropriate and answer the remainder of the questions

1. What is the runway elevation at Olympia Airport (KOLM)?

2. What type of controlled airspace is centered on Olympia Airport (KOLM)?

3. What is the length of the leg between Olympia Airport (KOLM) and Seattle-Tacoma International Airport (KSEA)?

4. What is the VOR frequency of the VORTAC at Seattle-Tacoma International Airport (KSEA)?

5. What is the control tower frequency at Seattle-Tacoma International Airport (KSEA)?

6. If you were told to divert to NAS Whidbey Island (KNUW) from Snohomish County (KPAE) how long would it take you to arrive at NAS Whidbey traveling at 100 Kts?

7. Estimate the distance from Snohomish County Airport (KPAE) to the nearest edge of the restricted airspace located south of NAS Whidbey Island (KNUW)?

8. What is the floor height of the Class B airspace over Snohomish County Airport (KPAE)?

9. What is the name of the first airport located due East of Snohomish County Airport (KPAE)?

10. Time to complete. ____________________
3.7.2 Flight Plan B

1. Subject is given a VFR sectional with the flight Plan clearly marked and the MFD is loaded with the same flight plan. Flight Plan B is as follows.

   A) Waypoint 1: Deland Municipal (KDED)
   B) Waypoint 2: Orlando Sanford (KSFB)
   C) Waypoint 3: Ormond Beach (KOMN)
   D) Alternate Destination: Flagler County (X47)

2. Initial Conditions:

   A) MFD

      a MFD is turned on with flight plan visible.
      b Aircraft symbol will be centered on Waypoint 2 moving at zero knots.
      c Map display range will be set to 20 nm
      d Data Block initial conditions set same as Flight Plan A.

   B) VFR Sectional

      a Subject will be handed a VFR Sectional with the proposed flight plan clearly marked in yellow highlighter.
      b Sectional will be folded and the subject will be allowed to unfold and configure the sectional (without cutting or writing on it) as they see fit.

3. Subject is afforded time to familiarize himself with the flight plan using either the MFD or sectional. The subject is instructed that they are allowed to manipulate the display in any way from the initial conditions once the evaluation begins. When the
subject declares himself ready to proceed, continue with next step. Record the amount of time subject takes to prepare.

4. **Flight Plan B Task List**

   A) State the full name of the departure airport
   
   B) State the course of the first leg of flight
   
   C) State the common traffic advisory frequency (CTAF) you would use for takeoff at Deland Taylor (KDED).
   
   D) State the type of special use airspace located about 15 nm west of Deland-Taylor Airport (KDED).
   
   E) State the height of the tallest obstacle within 10 nm of the first leg of flight.
   
   F) State the full name of the airport centered on the Class C airspace on the second leg of the flight.
   
   G) State an estimate of how long would it take to divert to Flagler County Airport (X47) from Ormond Beach (KOMN) if you were traveling at 100 knots?
   
   H) State the frequency of the NDB closest to Daytona International Airport (KDAB).

**Switch to other resource**

I) State the distance from Waypoint 2 to Waypoint 3.
   
   J) State the ceiling altitude of the first Class B airspace encountered as you approach Orlando Sanford (KSFB) from Waypoint 1.
   
   K) State the general orientation of the runway(s) at Orlando Sanford (KSFB).
   
   L) State the altitude of the tallest obstacle within the class D airspace at Orlando Sanford (KSFB).
M) State the frequency of the control tower at Orlando Sanford (KSFB).

N) State the floor altitude of the last Class B airspace shelf you will fly under in route to Waypoint 3.

O) State the course you would take to divert to Flagler Co. (X47) from Ormond Beach (KOMN) if directed to do so.

P) State the runway elevation at Ormond Beach (KOMN).

3.7.3 Flight Plan C

1. Subject is given a VFR sectional with the flight Plan clearly marked and the MFD is loaded with the same flight plan. Flight Plan C is as follows.

   A) Waypoint 1: Herlong Airport (23J)
   B) Waypoint 3: Jacksonville International (KJAX)
   C) Waypoint 3: Fernandina Beach (55J)
   D) Alternate Destination: St. Mary’s Airport (4J6)

2. Initial Conditions:

   A) MFD
      a) MFD is turned on with flight plan visible.
      b) Aircraft symbol will be centered on Waypoint 2 moving at zero knots.
      c) Map display range will be set to 20 nm
      d) Data Block initial conditions set same as Flight Plan A.

   B) VFR Sectional
      a) Subject will be handed a VFR Sectional with the proposed flight plan clearly marked in yellow highlighter.
b. Sectional will be folded and the subject will be allowed to unfold and configure the sectional (without cutting or writing on it) as they see fit.

3. Subject is afforded time to familiarize himself with the flight plan using either the MFD or sectional. The subject is instructed that they are allowed to manipulate the display in any way from the initial conditions once the evaluation begins. When the subject declares himself ready to proceed, continue with next step. Record the amount of time subject takes to prepare.

4. **Flight Plan C Task List**

   A) State the altitude of the departure airport (23J).

   B) State the length of the first leg of the flight.

   C) State the course to fly direct to your destination airport (55J) from Herlong (23J) or (KHEG).

   D) State the frequency for Automated Weather Observation Station (AWOS) at Herlong Airport (23J).

   E) State the kind of controlled airspace centered on NAS Jacksonville (KNIP).

   F) State the control tower frequency for Jacksonville International (KJAX).

   G) State the ceiling altitude of the outer ring of Class C airspace at centered on Jacksonville International (KJAX).

   H) State the general runway orientation at Jacksonville International.

Switch to other resource

I) State the name of the NDB navigation aid located approximately 7 nm southwest of Jacksonville International (KJAX).
J) State the CTAF frequency at Fernandina Beach (55J).

K) State the altitude of the tallest obstacle along the course from Jacksonville International (KJAX) to Fernandina Beach (55J), within 5nm of the proposed track.

L) State the distance between Waypoint 2 and Waypoint 3.

M) State floor altitude of the outer shelf of Class C airspace you will fly out of between Waypoint 2 and Waypoint 3.

N) State the course to your divert at St. Mary’s (4J6) from Fernandina Beach (55J).

O) State the runway length at St Mary’s (4J6).

P) Estimate the time it will take to divert to St Mary’s (4J6) from Fernandina Beach (55J) at 100kts.

### 3.7.4 Flight Plan D

1. Subject is given a VFR sectional with the flight Plan clearly marked and the MFD is loaded with the same flight plan. Flight Plan D is as follows.
   
   A) Waypoint 1: Orlando Country (X04)
   
   B) Waypoint 2: Kissimmee Muni. (KISM)
   
   C) Waypoint 3: Merritt Island (KCOI)
   
   D) Alternate: Space Coast Regional (KTIX)

2. Initial Conditions:

   A) MFD

      a MFD is turned on with flight plan visible.
b Aircraft symbol will be centered on Waypoint 2 moving at zero
knots.

c Map display range will be set to 20 nm

d Data Block initial conditions set same as Flight Plan A.

B) VFR Sectional

a Subject will be handed a VFR Sectional with the proposed flight
plan clearly marked in yellow highlighter.

b Sectional will be folded and the subject will be allowed to unfold
and configure the sectional (without cutting or writing on it) as they
see fit.

3. Subject is afforded time to familiarize himself with the flight plan using either the
MFD or sectional. The subject is instructed that they are allowed to manipulate the
display in any way from the initial conditions once the evaluation begins. When the
subject declares himself ready to proceed, continue with next step. Record the
amount of time subject takes to prepare.

4. Flight Plan D Task List

A) State the common traffic advisory frequency at the departure airport.

B) State the type of airspace Orlando Country Airport (X04) is located beneath.

C) State the course of the first leg of the flight.

D) State the distance at your closest point of approach to Orlando Executive
Airport (ORL) during the first leg.

E) State the floor altitude of the Class B airspace located over Kissimmee
Municipal Airport (KISM)
F) State the control tower frequency at Kissimmee Airport (KISM).

G) Estimate the distance from Kissimmee Airport (KISM) to Orlando International Airport (KMCO).

H) State the general runway orientation of the runways at Orlando International (KMCO).

Switch to other resource

I) State the VOR frequency of the Orlando VORTAC (ORL) located approximately 16 nm northeast Kissimmee Airport (KISM).

J) State the distance between Waypoint 2 and Waypoint 3.

K) State the height of the tallest obstacle within 5 nm of the course between Waypoint 2 and Waypoint 3.

L) State the frequency for receiving weather information about Kissimmee Airport (KISM).

M) State the floor altitude of the last shelf of Class B airspace you fly through on the way to Merritt Island (KCOI)

N) State the airport elevation for Merritt Island Airport (KCOI).

O) State the general runway orientation for Merritt Island Airport (KCOI).

P) State the type of controlled airspace centered on your alternate, Space Coast Regional Airport (KTIX).

Q) Estimate the time it would take to travel to the alternate, Space Coast Regional (KTIX) from Merritt Island airport (KCOI) at 100 kts.
3.7.5 Flight Plan E

1. Subject is given a VFR sectional with the flight Plan clearly marked and the MFD is loaded with the same flight plan. Flight Plan E is as follows.
   A) Waypoint 1: Portland International (KPDX)
   B) Waypoint 2: Portland Hillsboro (KHIO)
   C) Waypoint 3: Portland Troutdale (KTTD)
   D) Alternate Airport: Grove (1W1)

2. Initial Conditions:
   A) MFD
      a MFD is turned on with flight plan visible.
      b Aircraft symbol will be centered on Waypoint 1 moving at zero knots.
      c Map display range will be set to 20 nm
      d Data Block initial conditions set same as Flight Plan A.
   B) VFR Sectional
      a Subject will be handed a VFR Sectional with the proposed flight plan clearly marked in yellow highlighter.
      b Sectional will be folded and the subject will be allowed to unfold and configure the sectional (without cutting or writing on it) as they see fit.

3. Subject is afforded time to familiarize himself with the flight plan using either the MFD or sectional. The subject is instructed that they are allowed to manipulate the display in any way from the initial conditions once the evaluation begins. When the
subject declares himself ready to proceed, continue with next step. Record the amount of time subject takes to prepare.

4. **Flight Plan E Task List**

   A) State runway length at Portland International (KPDX).
   
   B) State the approximate time to travel the first leg of the flight plan at 100 knots.
   
   C) State the ceiling altitude of the outer ring of the Class C airspace around Portland International (KPDX).
   
   D) State the altitude of the highest obstacle within 5 nm of the first leg of the flight.
   
   E) State the control tower frequency for the Portland-Hillsboro (KHIO) Airport.
   
   F) State the bearing from Portland-Hillsboro (KHIO) to the Newburg VORTAC (UBG) located approximately 11 nm to the south of Hillsboro.
   
   G) State the course for the second leg of the flight.

   **Switch to other resource**

   H) State the floor altitude of the first Class C shelf the proposed track will fly through on the second leg.
   
   I) State the distance between Waypoint 2 and Waypoint 3.
   
   J) State the course you would fly to proceed direct from Waypoint 2 direct to your alternate at Grove Airport (1W1).
   
   K) State the type of controlled airspace centered on Portland-Troutdale (KTTD).
   
   L) State the altitude of the destination airfield Portland-Troutdale (KTTD).
   
   M) State the general runway orientation at the alternate, Grove Airport (1W1).
N) State the height of the tallest obstacle within the Class D airspace at Portland-Troudtale Airport (KTTD).

O) State the number of airfield(s) with services located within the Portland International (KPDX) Class C controlled airspace.

3.8 Subjective Evaluations

Test subjects completed two types of subjective evaluations. Modified Cooper-Harper evaluations were completed after each flight plan as well as two subjective questionnaires, one each at the midpoint and end of the study. A complete summary of all the comments from the subjective evaluations is available in Appendix C. Appendix C is ordered by subjects as well as in the same sequence the evaluations were administered.

3.8.1 Cooper-Harper Evaluations

Modified Cooper-Harper (CH) Evaluations were performed at the completion of each flight to determine the pilot’s perception of specific tasks regarding the manipulation of the MFD. Each questionnaire attempted to quantify the workload differences between the pilot’s use of the MFD for data mining and situational awareness enhancement vs. the same perceptions while using VFR sectionals. Subjects were encouraged to write down comments for each of the CH tasks with amplifying information. The tasks for the four different flight simulations and an example of the Modified Cooper-Harper evaluation chart are noted below.

<table>
<thead>
<tr>
<th>Flight Plan B Tasks</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Identify towers and other similar hazards to navigation. MFD</td>
<td></td>
</tr>
<tr>
<td>2 Identify towers and other similar hazards to navigation. -Sectional</td>
<td></td>
</tr>
<tr>
<td>3 Locate airport communication frequencies- MFD</td>
<td></td>
</tr>
<tr>
<td>4 Locate airport communication frequencies – Sectional</td>
<td></td>
</tr>
<tr>
<td>5 Estimate distance- MFD</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Estimate distance- Sectional</td>
</tr>
<tr>
<td>---</td>
<td>-----------------------------</td>
</tr>
<tr>
<td></td>
<td>Flight Plan C Tasks</td>
</tr>
<tr>
<td>1</td>
<td>Identify controlled airspace restrictions. – MFD</td>
</tr>
<tr>
<td>2</td>
<td>Identify controlled airspace restrictions. – Sectional</td>
</tr>
<tr>
<td>3</td>
<td>Locate available navigation aids and/or their frequencies- MFD</td>
</tr>
<tr>
<td>4</td>
<td>Locate available navigation aids and/or their frequencies - Sectional</td>
</tr>
<tr>
<td>5</td>
<td>Estimate course- MFD</td>
</tr>
<tr>
<td>6</td>
<td>Estimate course- Sectional</td>
</tr>
<tr>
<td></td>
<td>Flight Plan D Tasks</td>
</tr>
<tr>
<td>1</td>
<td>Ability of user to read and interpret available information. - MFD</td>
</tr>
<tr>
<td>2</td>
<td>Assessing time/distance from the aircraft to map specified objects. - MFD</td>
</tr>
<tr>
<td>3</td>
<td>Identifying potential hazards to flight, e.g. obstacles, airspace, etc. - MFD</td>
</tr>
<tr>
<td>4</td>
<td>Finding useful information at approach, destination, or along flight path. - MFD</td>
</tr>
<tr>
<td></td>
<td>Flight Plan E Tasks</td>
</tr>
<tr>
<td>1</td>
<td>Ability of user to read and interpret available information. -Sectional</td>
</tr>
<tr>
<td>2</td>
<td>Assessing time/distance from the aircraft to map specified objects. -Sectional</td>
</tr>
<tr>
<td>3</td>
<td>Identifying potential hazards to flight, e.g. obstacles, airspace, etc. -Sectional</td>
</tr>
<tr>
<td>4</td>
<td>Finding useful information at approach, destination, or along flight path. -Sectional</td>
</tr>
</tbody>
</table>

Figure 3.3: Summary of the Modified Cooper-Harper Flight Plan Tasks
Difficulty | Operator Demand Level | Rating
---|---|---
Very Easy, Highly Desirable | Operator mental effort is minimal and desired performance is easily attainable | 1
Easy, Desirable | Operator mental effort is low and desired performance is attainable | 2
Fair, Mild Difficulty | Acceptable operator mental effort is required to attain adequate system performance | 3
Minor but annoying difficulty | Moderately high operator mental effort is required to attain system performance | 4
Moderately objectionable difficulty | High operator mental effort is required to attain adequate system performance | 5
Very objectionable but tolerable difficulty | Maximum operator mental effort is required to attain adequate system performance | 6
Major difficulty | Maximum operator mental effort is required to attain adequate system performance | 7
Major difficulty | Maximum operator mental effort is required to avoid large or numerous errors | 8
Major difficulty | Intense operator mental effort is required to accomplish task, but frequent numerous errors persist | 9
Impossible | Instructed task cannot be accomplished reliably. | 10

Figure 3.4: Sample Modified Cooper-Harper Scale
3.8.2 Subjective Questionnaires

Subjects were asked to fill out subjective questionnaires at the completion of Flight Plan C and Flight Plan E. Paragraphs 3.8.2.1 and 3.8.2.2 list the questions in each questionnaire the subjects had to answer. Subjects could take as much room as needed to answer the questions. A summary of all the subjective questionnaires and the subject responses is found in Appendix C

3.8.2.1 MFD User Interface

Part I: Administer after flight Plan C.

1. What are the best features of the MFD user interface?
2. What are the worst features of the MFD user interface?
3. What specific things would you like to see different?

3.8.2.2 MFD Map and Information Content

Part II: Administer after completion of Flight Plan E

1. What do you like the most about the manner information is displayed and the available content?
2. What do you like the least about the manner information is displayed and the available content?
3. What would you like to see different about the about the manner information is displayed and the available content?

4. Results

During the formal evaluation, data was collected to determine the time it took to complete each event. Additional information was recorded regarding the number of erroneous answers reported by the test subjects as well as the magnitude of the error (in percent) for the answers that were given when estimating time, course, or distance. The data was then analyzed to address the question as to whether or not the Avidyne EX5000C, through the elegance of its
design, can be relied on to reduce pilot workload as well as enhance situational awareness while performing these tasks.

4.1 Summary of Events and Times

A total of 512 event tasks were completed over the eight test subjects and four flight plans (B-E). Of the 512 events, an equal number of event items were completed using the MFD or VFR Sectional exclusively. The sum of the event times, broken down by the use of each resource, is graphically portrayed in Figure 4.1.

It is clear from Figure 4.1 that a rather large gap exists between the total of the event times it took to complete events using the MFD versus using a sectional. In fact, over the 512 events nearly twice as much time was spent answering the questions with the MFD as was needed to answer identical questions with the Sectional. This equates to sixty-two percent of the total event time going to the use of the MFD. Moreover, the average time per event using the MFD was 73% longer than average time per event using the sectional (Figure 4.2).
Figure 4.1: Total Event Times

Figure 4.2: Average Event Times
The initial analysis of these results separated MFD and Sectional usage times by Flight Plan. Each flight plan event was completed an equal number of times using the Sectional and the MFD. Figure 4.3 summarizes the results by flight plan and the associated cumulative event time. This figure illustrates the recurring pattern across all of the flight plans of subjects using the MFD requiring greater time to accomplish the identical tasks performed with a sectional.

A T-test analysis of the data was performed to determine if a positive difference correlation existed in the longer event times for the MFD versus the sectional. A positive correlation would indicate the MFD was increasing the time to perform an event. Because it was clear from Figure 4.2 that the MFD was taken more time in each flight plan, the null hypothesis for the test argued that the MFD had no impact on the total event time. The results of the T-test showed a near positive correlation (p<0.10).

Some of the correlation should be attributed to familiarity and learning effects. All of the subjects were familiar with a VFR sectional before starting the test, and despite practice with
Flight Plan A, time was still needed to further learn and understand the MFD. A closer look at Figure 4.3 shows the greatest disparity between the MFD and Sectional appears in Flight Plan B. Flight Plan B covered a complex airport environment in the Orlando, FL region and was the first evaluation period after the practice flight plan. Nonetheless, the learning effects witnessed in this evaluation will be common to all GA pilots adopting the EX5000C and the results should not necessarily be viewed as non-representative of the target market. Removing the data from Flight Plan B will most certainly reduce the near significance of the T analysis and further research into all of the data’s implications is warranted.

4.2 Summary of Event Times by Event Type.

The Department of Transportation performed a study in 2001 that showed the value of having a well-organized display for reducing pilot workload (DOT, 2000). In the DOT study, 27 pilots were asked to prioritize information that would be useful during different phases of flight. The top information priorities for in-flight planning were Time-ETA/ETE, Distance, Fuel Quantity, Waypoints, General Weather, Course, Altitude-MSL, Heading, Wind, Airport Configuration, ATC Communications, Groundspeed, and Airspace. This list is rather lengthy but for the experienced pilots surveyed, each of them were given nearly equal priority. Obviously, the MFD has no capability to display some of this information and other bits are aircraft specific, but Time, Distance, Waypoints, Course, Airport Configuration, ATC communications, and Airspace are pieces of information that the EX5000 is intended to provide.

To this end, test data was further broken down by event type. The test subjects performed a total of 512 events over the course of the four flights. An equal number of responses came from the MFD as from the VFR Sectional. All questions were then organized by type and grouped into seven different categories. The categories are Airport Information, Time
and Distance estimates, Airspace Altitudes, Obstacle information, General Map Information, Course Estimates, and Navigation Aid (Navaid) information. The event categories and their associated summed times and averages are shown in Figure 4.4 and graphically in Figure 4.5 and 4.6 below.

### All Flight Plans

<table>
<thead>
<tr>
<th>Event Type</th>
<th># of Events</th>
<th>Event Time</th>
<th>Average Time/Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>Airport Info</td>
<td>176</td>
<td>0:27:27</td>
<td>0:00:09</td>
</tr>
<tr>
<td>Time/Distance</td>
<td>88</td>
<td>0:35:35</td>
<td>0:00:24</td>
</tr>
<tr>
<td>Airspace Altitudes</td>
<td>64</td>
<td>0:14:05</td>
<td>0:00:13</td>
</tr>
<tr>
<td>Obstacles</td>
<td>48</td>
<td>0:12:57</td>
<td>0:00:16</td>
</tr>
<tr>
<td>General Map Info</td>
<td>48</td>
<td>0:05:54</td>
<td>0:00:07</td>
</tr>
<tr>
<td>Course Info</td>
<td>64</td>
<td>0:18:52</td>
<td>0:00:18</td>
</tr>
<tr>
<td>Navaid Info</td>
<td>24</td>
<td>0:13:35</td>
<td>0:00:34</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>512</strong></td>
<td><strong>2:08:25</strong></td>
<td><strong>0:00:15</strong></td>
</tr>
</tbody>
</table>

### All Flight Plans-MFD

<table>
<thead>
<tr>
<th>Event Type</th>
<th># of Events</th>
<th>Event Time</th>
<th>Average Time/Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>Airport Info</td>
<td>88</td>
<td>0:19:26</td>
<td>0:00:13</td>
</tr>
<tr>
<td>Time/Distance</td>
<td>44</td>
<td>0:20:00</td>
<td>0:00:27</td>
</tr>
<tr>
<td>Airspace Altitudes</td>
<td>32</td>
<td>0:08:48</td>
<td>0:00:17</td>
</tr>
<tr>
<td>Obstacles</td>
<td>24</td>
<td>0:08:00</td>
<td>0:00:20</td>
</tr>
<tr>
<td>General Map Info</td>
<td>24</td>
<td>0:03:28</td>
<td>0:00:09</td>
</tr>
<tr>
<td>Course Info</td>
<td>32</td>
<td>0:10:58</td>
<td>0:00:21</td>
</tr>
<tr>
<td>Navaid Info</td>
<td>12</td>
<td>0:09:29</td>
<td>0:00:47</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>256</strong></td>
<td><strong>1:20:09</strong></td>
<td><strong>0:00:19</strong></td>
</tr>
</tbody>
</table>

### All Flight Plans-Sectional

<table>
<thead>
<tr>
<th>Event Type</th>
<th># of Events</th>
<th>Event Time</th>
<th>Average Time/Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>Airport Info</td>
<td>88</td>
<td>0:08:01</td>
<td>0:00:05</td>
</tr>
<tr>
<td>Time/Distance</td>
<td>44</td>
<td>0:15:35</td>
<td>0:00:21</td>
</tr>
<tr>
<td>Airspace Altitudes</td>
<td>32</td>
<td>0:05:17</td>
<td>0:00:10</td>
</tr>
<tr>
<td>Obstacles</td>
<td>24</td>
<td>0:04:57</td>
<td>0:00:12</td>
</tr>
<tr>
<td>General Map Info</td>
<td>24</td>
<td>0:02:26</td>
<td>0:00:06</td>
</tr>
<tr>
<td>Course Info</td>
<td>32</td>
<td>0:07:54</td>
<td>0:00:15</td>
</tr>
<tr>
<td>Navaid Info</td>
<td>12</td>
<td>0:04:06</td>
<td>0:00:21</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>256</strong></td>
<td><strong>0:48:16</strong></td>
<td><strong>0:00:11</strong></td>
</tr>
</tbody>
</table>

Figure 4.4: Event Summary by Type
Figure 4.5: Summary of Event Time by Type

Figure 4.6: Average Time per Event by Type
With the data organized in this manner, another T-Test was performed with markedly different results from the Flight Plan based test. Organizing by type yielded a strong positive correlation between use of the MFD and increasing event time (p<0.05). The statistical analysis confirmed what seemed intuitive from the data- using the MFD to retrieve information took longer than simply using a VFR sectional.

### 4.3 Subject Errors

Most of the tasks performed could be correctly answered with precise information from the MFD or sectional. Subject answers for these questions could be assessed as either correct or incorrect. Other tasks could require a test subject to make estimates of distance, course, or ETE using whatever directing measuring methods at their disposal. Subject answers for these kinds of questions were measured relative to the exact answer known only by the evaluator.

Among the 374 questions that could be assessed as correct or incorrect, test subjects reported 20 of the answers incorrectly, or once every 19 tasks. Considering the low-pressure nature of the test, it is surprising to note even this number of errors. Of these 19 errors, 65% occurred using the MFD and 35% happened while looking at a sectional (Figure 4.7).

![Errors by Resource](image)

Figure 4.7: Percentage of Incorrect Answers by Resource
Most errors from the MFD occurred interpreting altitude information for obstacles. (Figure 4.8)

This seems understandable given the high clutter density most test subjects worked with during the course of the test. Only three test subjects regularly tried to use the declutter button to see things better and only one went back to the Declutter Setup page and turned the high and low obstacles from the always “on” setting to the “auto setting. The result was that in tower dense airport or city environments, careful scrutinization was required to pick out the correct information. With more experience, test subjects would likely remember this feature and use it more regularly in high-density map areas. In addition to these obstacle challenges, another 38% of the MFD errors came from interpreting Airspace altitude information. When viewed in light of the subjective written and verbal comments from the test subjects, it is also consistent with the general frustration felt by the subjects trying to identify and/or interpret correct altitude restrictions.

![MFD Error Distribution](image)

Figure 4.8: MFD Error distribution
Errors using the VFR sectional were more evenly distributed (Figure 4.9) but still more heavily weighted toward problems identifying airspace altitude restrictions and obstacles heights. A common problem using the sectional was picking out the correct information in the densely cluttered map environments. Subjects incorrectly associating numeric information with the wrong map symbol was the common source of the incorrect answers. This led to additional errors in other category types as the clutter density obscured all information types equally.

![Sectional Error Distribution](image)

**Figure 4.9: Errors by Type and Resource**

Despite similar problems even when using sectionals, the combined value of MFD airspace and obstacles errors alone represents 55 percent of the total errors over the entire test.

Some of the subject answers also involved the old-fashioned eyeball method of estimating distances or bearings. All totaled, subjects reported 138 answers that were actually an estimation based on their own individualized estimation techniques. Estimations answers were given for distance measures, course measures, and ETE measures. Sometimes, information that had to be estimated on the VFR Sectional could be precisely viewed on one of the pages of the MFD. Subjects were not directed how to arrive at their answer or where to go for the information. This resulted in a unique number estimates that could be associated by subject or question. For
purposes of this analysis, an answer that was estimated was one where the test subject attempted to directly measure distance or bearing on the map page of the MFD. All distance and course answers are considered estimates while the subject was using the sectional. All totaled, there were 64 Course estimates (32 MFD, 32 Sectional) and 74 distance estimates (32 MFD, 42 Sectional). Since time estimations are essentially distance estimates with an extra step, their results were grouped with the pure distance type tasks.

To measure distance, subjects might mark a piece of paper, mark the range between points on their writing device, or fix their fingers to the distance, and then move the measuring device to a readable scale. The more experienced pilots would estimate distances from other objects of known length already visible on the sectional or MFD. The range rings of Class D or C airspace was one such object. All of the distance estimates were between points that were easily and precisely defined on both the MFD and Sectional. To make course estimates, subjects most commonly would aligning a straight edge across a new course and moving the line in parallel to a visible compass rose.

A summary of the average percent error from the known actual values shows that generally speaking, pilots are not too bad at estimating courses to fly, and fairly poor at estimating distances. Subjects using the MFD were slightly less accurate estimating courses than subjects using the VFR Sectional (average error 3.1% with MFD vs. average error of 1.3% with Sectional- Figure 4.10). Additionally, subjects estimating distances with the MFD were again less accurate than when estimating with the sectional (Sectional average distance error 27.3% vs. 16.8% with MFD- Figure 4.11). Neither resource was particularly good at distance estimations but the improvement with the sectional seems understandable given pilot familiarity and the multitude of ways to measure distance available on a sectional. Nonetheless, subjective
comments reveal general frustration with all test subjects using the MFD for either of these types of exercises.

Figure 4.10: Average Course Estimation Error

Figure 4.11: Average Distance Estimation Error
4.4 Cooper Harper Results

Each subject was asked to assign a total of 20 Cooper-Harper scores over the four flights. A complete list of the task items can be found in section 6.6.1 of this document. There were an equal number of task items associated with the sectional as with the MFD. Additionally, an identical question was posed using each resource to provide a direct line of comparison. Unfortunately, the Cooper-Harper evaluations were inconclusive. Generally speaking, subjects evaluations for MFD related tasks were generally worse than for the same VFR Sectional related tasks. The averages across all test subjects and tasks were 3.2 for MFD tasks and 2.6 for VFR Sectional tasks. Figures 4.12 summarize the raw score results for these evaluations.

<table>
<thead>
<tr>
<th>Task</th>
<th>S1</th>
<th>S2</th>
<th>S3</th>
<th>S4</th>
<th>S5</th>
<th>S6</th>
<th>S7</th>
<th>S8</th>
<th>Averages</th>
<th>Resource</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>2</td>
<td>7</td>
<td>3</td>
<td>5</td>
<td>3</td>
<td>2</td>
<td>3</td>
<td>3.4</td>
<td>MFD</td>
</tr>
<tr>
<td>2</td>
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<td>3.8</td>
<td>MFD</td>
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<td>6</td>
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<td>3</td>
<td>2</td>
<td>1</td>
<td>2.5</td>
<td>Sectional</td>
</tr>
</tbody>
</table>

| Flight Plan B | 1 | 3 | 8 | 3 | 2 | 7 | 1 | 2 | 5 | 3.9 | MFD |
| Flight Plan C | 2 | 2 | 1 | 3 | 3 | 1 | 3 | 1 | 2.1 | Sectional |
| Flight Plan D | 3 | 3 | 3 | 2 | 3 | 3 | 2 | 2 | 4 | 2.8 | MFD |
| Flight Plan E | 4 | 2 | 1 | 3 | 3 | 2 | 1 | 4 | 1 | 2.1 | Sectional |
| Flight Plan D | 5 | 3 | 2 | 2 | 3 | 2 | 2 | 3 | 3 | 2.5 | MFD |
| Flight Plan E | 6 | 3 | 2 | 2 | 3 | 4 | 2 | 4 | 2 | 2.8 | Sectional |

Figure 4.12: Cooper Harper Scores Summary
Three histograms from the raw scores were also created to show the general scoring break down by resource. Figures 4.13, 4.14 and an aggregate histogram in Figure 4.15 show the propensity for the scores on both devices towards lower numbers. The scores seem generally consistent with the test subjects overall strong impression of each device but with a tendency to prefer the Sectional to the MFD when performing these kinds of tasks.

Figure 4.13: Cooper Harper Sectional Histogram

Figure 4.14: Cooper Harper MFD Histogram
4.5 Results Summary

A snapshot of the data analysis can be summarized as follows.

Test Subjects

- Test subjects had an average of 1100 hours of flight experience with 300 hours average Instrument time.
- The test subjects’ experience covered a large swath of the spectrum of general aviation pilots.
- Test subjects were comfortable using VFR Sectionals and all had experience with hand-held GPS devices and/or MFDs.

Event Times:

- Analysis in the disparity between total MFD event time and total Sectional event time was compared by flight plan and by event type.
- Analysis by flight plan showed weak positive correlation for use of the MFD causing an increase in event time (p<0.10).
Analysis by event type showed strong a positive correlation for use of the MFD causing an increase in event time (p>0.5).

It is reasonable to conclude that learning effects and/or experience with a VFR sectional is not a compelling enough argument to explain the positive correlation.

Use of the MFD increases the workload of the pilot over use of a VFR sectional to complete these tasks.

Errors:

Twenty out of a possible 374 answers were reported incorrectly by test subjects using both devices.

A much higher percentage of the total errors occurred while using the MFD (65% MFD, 35% Sectional).

The greatest source of all errors occurred using the MFD to determine altitude restrictions over controlled airspace and altitude information about obstacles (55%).

Subjects responded to 138 of the questions by making on screen estimations of distance or course.

The average percent deviation of course estimates from actual values was greater using the MFD than course estimates using the sectional (3.1% MFD, 1.3% Sectional).

The average percent deviation of distance estimates from actual values was substantially greater using the MFD than distance estimates using the sectional (27.3% MFD, 16.8% Sectional).
5.0 Recommendations

The Avidyne EX5000 MFD is intended for use across a wide spectrum of general aviation missions. The large glass display is very appealing and has thrilled everyone who has used it. Avidyne believes that pilots flying with the EX5000 MFD should enjoy reduced workload and improved situational awareness. This evaluation cannot measure that claim in a comprehensive or robust manner. However, the evaluation does examine one of the ways in which the Avidyne MFD will likely be used and points out some areas where some improvements are in order. The recommendations that follow are based in part on the results of the data analysis and in part on general human factors engineering theory. In cases where the recommendations are not explicitly working to reduce the time to complete tasks or reduce error, they are intended to improve general functionality by leveraging accepted human factors design principles. Many of the recommendations are derived from the Human Factors Design Guide Update (DOT 2001) and the Human Factors Design Guidelines for Multifunction Displays (DOT 2001). Other recommendations are based on personal experience, recommendations from the test subjects, and other academic and professional sources.

One of the MFD’s primary functions is as an information relay and interpreter between the aircraft’s operating environment and the pilot. As such, it is important to understand the EX5000’s performance at this task relative to what a pilot may want it to do. During the evaluation, subjects were asked to retrieve information that was structured to simulate in-flight planning questions that a pilot may have to answer on a simple VFR flight plan. From the analysis of the results it was clear that the EX5000 was more inclined to error and was having an undesirable impact on the time it took to retrieve information regarding the route of flight.
5.1 Interactive Map

A VFR sectional has advantages over the MFD that allow a user to subconsciously customize the information they receive. First, a VFR sectional is always at the same scale and the information on the Sectional is fixed in both position and content. Despite the near universal dislike of the clutter on a sectional, once an item is found the first time, it is very easy to find it the next time and so on. Moreover, information is clustered so that associated information can be found at the same location as previously found information. An airport elevation and airport control frequency are one example. Lastly, the VFR Sectional puts pertinent information near the location on the map a user will be looking, i.e., airport information on the Seattle-Tacoma airport is located near the airport symbology for Seattle-Tacoma airport. A pilot that is aware of their general location on a sectional immediately knows what is around them and can find amplifying information without looking elsewhere. As can be seen from the test results, these basic advantages contributed to a significant reduction in the time it took for pilots to retrieve information pertinent to their planned flight. In terms of pilot workload and its impact on situational awareness while accomplishing these basic tasks, it would seem that the MFD is falling short of its intended purpose.

The best way to drastically reduce and probably even improve the time to complete information retrieval type events with the MFD is to build in a dynamic pilot interface that allows the pilot to call up important information directly from the map page. Through a pilot controlled device, an icon on the map screen could be maneuvered to map symbology that could then be prompted for amplifying information. Ideally a pop-up window would briefly overlay a portion of the map display while a pilot reads the necessary information and could then be cleared from the screen. The information in the pop-up would provide the information necessary
to satisfy immediate pilot concerns with access to further, more comprehensive information, such as an airport information page, accessible directly from the same pop-up window.

Fundamentally, it is important that the time away from the Map page is reduced and information becomes more easily accessible to the pilot. Unquestionably, the universal frustration with the Avidyne EX5000 MFD was the inability of the user to view information that they wanted when they wanted. All subjects voiced a very strong desire to be able to select items from the map page to be amplified for more information without having to resort to navigating through menu buttons.

From a human factors perspective, this makes complete sense. For example, imagine that a pilot would like to practice VFR approaches and landings at an airfield along their route of flight. The pilot is proactive and wants to plan ahead for the airfield and seeks the local weather information at the field. He then turns to the EX5000C to get the local airport weather advisory frequency and goes through the following procedure. 1). The pilot easily spots the airport on the MFD map page, 2). Commits the three or four letter alpha-numeric airport identifier to memory, 3). Rotates the raster switch to the “Nrst” page, 4). Scans through an unfamiliar and changing list of airports that are within 60 nm of the aircraft, 5). Matches either the same alphanumeric airport identifier or the airport name if it is known, 6). Pushes the “Airport Information” push-button to view the airport frequencies, 7.) Reads through another list of data to find the desired frequency, 8) Writes down, commits to memory, or perhaps tunes the desired frequency, and finally 9). Rolls the raster back to the “Map” page to regain situational awareness. The pilot must follow this fairly rigid nine-step process and move from the map page, through the airport information page, and back to the map page. A miscue in the process that takes the user away from the “Nrst” core
page will require the person to start all over. The steps and mental effort required of the pilot to retrieve this valuable information are simply prohibitive.

5.2 Basic Recommendations

Generally speaking, the Avidyne EX5000 is user friendly and intuitive. The function labels are easily understood and the results are easy to interpret. It's easy to demand a new device that allows the pilot to interface directly with the map but the reality of the dramatic software and hardware requirements that would be required may make this an unrealistic alternative. However, making the present design easier to learn, organizing information in a more logical and user friendly manner, and adding new functionality will reduce the time to train, event time, and error rates as well.

5.2.1

Make the EX5000C Pilot’s Guide available electronically from the MFD. An easy fix that can help users learn more about the device when there is time to spare.

5.2.2

Remove the up arrow and down arrow keys for scrolling (See Nearest Pages, Airport Filter and Declutter Setup figures for examples). These keys can add steps to any process where they are visible. Users can use the right raster function faster and more efficiently on any of the pages where these buttons appear. The raster knob does not require hand movement to the opposite directional button in case of an overshoot and removing the arrow keys will free up these function buttons for other uses.
5.2.3

*All pages should have clear instructions visible on the page.* Most in fact do have some kind of clarifying information but some users would be well served with better instructions.

**Declutter Setup:** Particularly problematic for the test subjects was the “Declutter Setup” page (Figure 2.8). The first two columns of information can be configured by the pilot and are labeled “Display” and “Label”. Unfortunately, the titles are not distinct enough and both can be interpreted to mean exactly the same thing.

The “Display” column actually refers to map navigation-aid symbology (including airports) that will be displayed on the map page. This column of information should be relabeled “Map Symbology” (or perhaps abbreviated “Symb”) to be clear. Further, the three pilot options for Display are “On”, “Off”, or “Auto”. Again, there is no explanation of the difference between “On” or “Auto” on the page but the “Off” option seems fairly intuitive. The EX5000 Pilot’s Guide explains that “On” means the information is always displayed and “Auto” means, “The Navaid is displayed automatically and declutters automatically based on the pixel density at a given range” (FlightMax, 2001). Again, this option does not seem so intuitive. For example, turning the “Low Obstacles” display option from “On” to “Auto” turns off all low obstacle information at the 20 nm range scale and higher. The pixel density in a particular location may start at 100% from the presence low obstacles but will go to 0% when set to Auto. If the range scale is now decreased in the “Auto” mode the low obstacles will reappear. Pixel density may very well go back up again depending again on the geography of the location. It appears that there is more going on than simply measuring pixel density. This illustration not only points out some of the frustrations a pilot may experience making the display perform as desired, but also illustrates how important it is to have very clear instructions available to the pilot.
The second “Label” column refers to the associated letters or numbers that can be displayed next to airport symbology or other line items. It can be check marked or left blank through pilot inputs. This column title can remain the same if the “Display” title is changed. The check mark activation feature should be changed to “On” or “Off” to remain consistent with the first column. Instructions should also be included at the top of the page to explain this feature.

Lastly, both columns are manipulated at the same time through a set sequence of display options. A user does not know the order or the options when making changes and has to repeatedly push the “Change Value” button to find the desired format. These options should be displayed in a single dropdown list that would appear when the “Change Value” button is pushed the first time. In this manner, users can spot the correct setting and move to it directly. Further, since both columns are being changed at the same time, the “Change Value” button should be changed to read “Change Values”. A different and more complex alternative would be to separate the symbology and label columns so that they can be individually set.

5.3 Page Recommendations

Again assuming an interactive Map page will not be the first improvement pursued for the MFD, there are ways to improve the current pages and make them more user friendly. Consistency between displays is a recurring theme as well as a desire to present some information in a more intuitive and user-friendly manner.

5.3.1 Data Blocks

The data blocks on the Map page are continuously updating snapshots of user-defined valuable information. Valuable insofar as the pilot wants this information always at their
disposal to quickly augment their situational awareness. One of the issues being addressed in this evaluation is the amount of time spent away from the Map page and its potential impact on situational awareness. The only page other than the Map with navigation information visible is the Trip page. Indeed the “Trip Page” has its own preset mini data blocks in the top corners and a Course Deviation Indicator (CDI) in the top center as well. The information from the Map Data Blocks is more complete and would be a familiar tool for a pilot to minimize the impact of the time away from the Map. For aircraft in flight, these data blocks coupled with the Trip page CDI should become page headers for all non-map pages.

5.3.2 Trip Page

The “Trip” page was met with very mixed reviews. One subject described it as “essentially useless” and another independent user of the MFD thought it was one of the most useful pages on the MFD. The value of this page really depends on what the user wants to know about their trip and when. First, the “Trip” page is not archival so once a pilot passes a waypoint the information from that leg disappears from the “Trip Page”. The “Map” page however continues to display the completed leg even after it is dropped from the “Trip” page. There is no compelling reason for keeping it or not keeping, but the information should be consistent across all of the pages. I recommend retaining that information on the Trip and Map pages as an easy reference to the complete(d) flight. Most of the subjects desired to have that information remain on the screen even after the leg was completed.

Second, the information in the columns next to the waypoints should be expanded to include leg information. The Trip page is ordered by waypoints from a flight plan. Next to the first waypoint identifier in the first column it states “To.” The rest of the row, in order, is “BRG DTK Dist(EST) ETE ETA”. Each subsequent row begins with the next waypoint in the
flight plan sequence with the each column filled with the appropriate information. What is not initially clear is that the Distance, ETA and ETA values for the second waypoint and down are cumulative from the current position on the flight plan and assume the aircraft follows the exact track of the flight plan. Remember, the first column says “To:” and then the Waypoint. Several test subjects assumed that the “To” applies to the next waypoints in the column as well and thought the following columns of data was information to fly directly “TO” those waypoints.

Other test subjects went to this page and noted that the bearing information corresponded to the correct bearing for the leg and incorrectly assumed the distance values to be the length of the leg to that waypoint as well. Organizing the information by legs instead of by waypoints could eliminate the confusion. Each data line should clearly state the distance, bearing, ETE, ETA, etc between two points. The columns should be titled “From, To, Course, Distance, DTK, ETE, ETA, Trip ETE, Trip Dist”. Trip information from the present position to the active waypoint could be broken out separately as it is in the Map page data blocks. This type of arrangement would also be consistent with the Map page view of the flight plan.

A second recommendation for this page is to be able to display amplifying information about waypoints as well as the destination airport. Many waypoints are airfields that require communications with control agencies, for example, and a look to the TRIP page should lead to quick access to all amplifying information. The “Destination Airport Info” button should be changed to “Waypoint Info”. Rotating the right raster should highlight waypoints from the nearest to the destination waypoint. Selecting “Waypoint Info” should bring amplifying information directly to the Trip page. If room is available, the information should be displayed without overlapping any other trip information. If that is not possible, the Trip page should be rearranged as necessary so as not to clutter the current line of trip information. VORs, NDBs or
other definable waypoints should have an information page that can be individually called up as well. A less desirable option would be selecting “Waypoint Info” taking the pilot to the appropriate “Airport Information” page as it is done currently. Amplifying information accessed in this manner should have a “Back to Trip” push button available to return the pilot quickly back to the trip page.

5.3.3 Nearest Page(s)

These pages represent the only source of amplifying information regarding much of the symbology displayed on the MFD Map page. As such, it is very important that the data is easy to find, easy to read, and valuable to the user. Additionally, it is important that the time spent on these pages is not any more than necessary as they provide no picture of the environment outside the cockpit.

Airport Information: Figures 2.10 and 2.11 show a screen shot of a representative “Nrst” airport page and the “Airport Information” page for Orlando International Airport (KMCO), respectively. Looking at Figure 2.10 now illustrates several key points. First, the airport names and identifiers blend in quite easily with each other. The airports are ordered by distance from the aircraft but the only information that can be picked up from the Map page is an alphanumeric identifier. The result is that a pilot ends up scanning the entire “Nrst” list trying to pick out the correct identifier. Finding an airport using a four-letter identifier can be particularly challenging on longer lists. Test subjects consistently commented on the difficulty of finding the desired line item of information on the “Nrst” page(s). Interestingly enough, as the aircraft was not moving in the evaluation, the lists were static in their order and not subject to the regularly re-ordering they would undergo as the airplane flew closer to or farther away from them. Another problem is illustrated in Figure 2.12. The airport identifier for KMCO has five Departure
Control, five Terminal Control, and eight Approach control frequencies listed. It is now up to the pilot to figure out which one is the appropriate one to use. Any pilot familiar with a VFR Sectional knows that the frequencies are associated with the direction of approach to or departure from the airfield. Imagine being a pilot in the busy Orlando Class B airspace, completing the nine steps required to get to the KMCO airport information page, only to discover you still have to guess at the correct frequency to talk with the control agencies. I believe steps ten and eleven would now be to break out the VFR Sectional and look up the frequencies there.

A partial solution to these problems would be to have the option of ordering the airports (and NDBs, VORs, and intersections) alphabetically. An alphabetical search will proceed much more quickly than a random scan. Also, airport information could be color coded to match the Map display- magenta for non-towered airfields and blue for towered. Further, the VOR and NDB nearest pages should be combined on the same Nearest page to eliminate pages, steps and time. Information that has the symbology turned off in the Declutter Setup pages should not appear on the nearest lists. A function should be included for emergencies, “All Nrst” push button perhaps, to override the filter if needs be. Elimination of the two up and down arrow push buttons as mentioned earlier and consolidating the VOR/NDB information will enable the Nearest core page to have dedicated push buttons for each of the VOR/NDB/Obstacles/Intersections nearest pages. Dedicated buttons will again reduce the time it takes to reach the desired information.

A final recommendation for these pages is to tweak the data to show the information in the way it would be used. This should be manifested in two ways. In the case of the Orlando International Airport, the approach frequencies are assigned to approach corridors. A simple map with an airfield centered and the frequencies placed in the appropriate quadrants would
make the information the most user-friendly. Otherwise, the frequencies should be listed with the appropriate usage guidance next to them and not in a plain list. The second way to improve the data is to add a function called “Show on Map”. Pressing this button would switch the user back to the Map page and briefly highlight or magnify the selected item. A bright green circle around the object would be one way of accomplishing this. In this manner, the user can quickly verify the location of the information they just investigated while simultaneously returning to the Map page.

5.3.4 Map Page

The Map page is the heart of the MFD. All usability issues with the other pages aside, on the Map page the EX5000C makes its claim for enhancing a pilot’s situational awareness. It is on the Map page that the real advantages of the MFD over the VFR sectional become readily apparent. Information on the map page is crisp, easy to see, and the symbology is nicely similar to the familiar VFR sectional. Even here, however, some small tweaks can add functionality and improve the elegance of the design.

**Map Legend:** Every map should come with a legend. The symbology of the MFD is a close match to a VFR sectional but they are not exact mirrors. While the subtleties are not huge it is worth having a ready reference to understand the exact meanings. A “Map Legend” page would be a nice addition, particularly for new users.

**Declutter:** Pushing this button makes the small triangle on the function label become less filled and causes screen symbology to disappear. Which items and in what sequence they disappear is left to the pilot to figure out. Several test subjects cycled through this button multiple times trying to understand the order in which symbols drop off. Most were unable to figure it out precisely and even the Pilot’s Handbook offers no clarification of the sequence of
events (FlightMax, 2001). Pressing this button should briefly flash a message with the items being suppressed from the display. Much like the message that flashes when the range ring is adjusted, a similar message with the associated symbology should appear when the declutter button is pushed.

**Map Center:** Participants reported frustration with always being tied to the aircraft’s position for viewing what was displayed on the Map. On long flight plans that do not fit neatly into a small range scale, scaling the map up to see the further destinations or waypoints was an unhappy compromise. Pilots wanted to inspect their entire flight plans at the smaller and clearer range scales to be able to understand what was coming up and plan ahead. By looking ahead and understanding what is coming up pilots will attempt to spread the workload across the entire flight instead of learning all the nuances of the area when they arrive. The map should have the capability to be centered, moved or referenced to display map information other than just around the aircraft. It is recommended to add a scrolling feature to enable moving the map display to view other areas at all scales. It is also recommended to add the ability to move map reference points to user-selected positions. To accomplish the first requirement, scrolling the center position on the map page, an added function button titled “Move Map” should be added to this page. Selecting this push button function will switch the four right function labels to directional arrows pointing in the four cardinal directions. Pushing the direction buttons will move the map display in the direction of the arrow. Aircraft track and data block information will continue to be updated and the data blocks should remain as well. A fifth function key titled (Recenter on Aircraft) would then appear in the Map view. The second capability to re-reference the map center and associated nearest information would be particularly useful on the Trip core page. From the Trip page, cycling through the waypoints should come with an associated function
allowing the map page to recenter at any of the waypoints. Nearest pages should update accordingly to the new waypoint center. Anytime the map is not centered on the aircraft, a function key must be dedicated to returning the map to the aircraft centered position.

**Time/Distance Calculations:** One of the simplest functions not easily performed on the MFD is measuring distances away from the aircraft or not associated with the proposed route. Computing the time and distance to a new alternate airport from a destination airport or interim waypoint cannot be easily accomplished with the MFD. The method is also crude for Sectionals but sectionals can be viewed equally well at any point along the flight, distances can be eyeballed with experience because the range never changes, and even then an accurate scale is always available for exact measurements. With the MFD, on longer flight plans the pilot may need to range up to very large scales to even see the far waypoints and translating course and distance information at the high ranges becomes inherently less accurate. Being able to move the map position away from the aircraft would allow pilots to stay at a smaller scale and have better accuracy. In the absence of an interactive device where distance could be measured directly on the screen, a simple alternative would be to publish time/distance/speed range scales vertically along the edge of the map. Ideally, the time bar could be calibrated to the aircraft speed and matching a measured distance with a pencil or other device would also correspond to the time to travel that distance. Time/Distance scales are found on VFR sectionals already and should be duplicated on the MFD.

**Airspace Information:** Misunderstanding controlled airspace restrictions, inconsistencies between sectional information and the MFD, and altogether missing altitude information when the feature label was turned “On” on the Declutter Setup page were all encountered in the four randomly selected flight plans. Simply put, this resource needs to be better implemented and
more clearly displayed on the map page. An accurate understanding of controlled airspace is one
the most important pieces of information a pilot needs to avoid a flight violation, and none of the
subjects felt comfortable with this MFD feature at the completion of the evaluation. I have no
new solution and can only reiterate that this information needs to be present, accurate, and well
placed on the map. Avidyne recognizes the inadequacy of this feature and has the Airspace
labels turned off in the VFR Default settings on the Declutter setup page. This appears to be a
poor dodge around an area of known weakness.

5.4 Avidyne Product Development Process

Human factors engineering should be a part of the product development process from the
beginning. Indeed, the genesis of the EX5000, the desire for a bigger piece of glass for viewing
a moving map display, was at its heart a human factors centered product idea. Bigger is better
for understanding the complex aviation environment on a moving map display. Avidyne,
however, waited until very late in the product development process to comprehensively test
much of the human factors qualities of this device. They know of course that a big display will
not in and of itself make the EX5000C a great product. Unfortunately, the reality of making the
big display work and integrating all of the systems that were proposed in the original plan was
much more difficult than anticipated. Within the original proposal to Cirrus for the SR20-22, the
EX5000 was supposed to be a full Flight Management System complete with ground based data
link capability for immediate flight plan and database updating and integrated engine monitoring
and diagnostics among other things. What ended up really driving the ball was hardware
development for the big display and pilot interfaces, followed by software integration, followed
by the need to make it easy enough to use so that a general aviation pilot can turn it on and really
reduce their workload and improve their situational awareness. It appears, however, that by the
time the resources were dedicated to the final step time was running out. Now a product has to be finished, FAA certified, manufactured and ready to deliver in time to meet the promised delivery date for its first customers. Human factors never got formal attention until near the very end and by then with little ability to influence or direct significant change. For example, early in the design process a decision was made not to have an interactive device for use on the map display. According to private testimony, the final decision against such a device was made for monetary reasons with only a cursory look to its human factors implications. It may still be the right decision but time and customer satisfaction will certainly be the final arbiter. In the future, Avidyne would be served well by an independent and concurrent human factors advisory team. Particularly in aviation, Avidyne does not want to make the critical mistake of building boxes that can fly but will not help keep the pilot safe while airborne.

6.0 Conclusion

The first impression of the EX5000C was near euphoric for all of the test subjects. Each of them remarked how they would love to have one in their cockpit and that they could clearly see the added value of the larger, crisp moving map display. However, beneath the positive underpinnings was a common feeling of frustration with some aspects of the device. Every subject listed critical ways in which the MFD should be improved and voiced surprise at many of its limitations. The end result was a feeling of great excitement and anticipation about its future potential with strong to mild enthusiasm for the current design.

In many ways the EX5000C is a capable and elegant design. The map graphics are clean, crisp and rich in detail. The push buttons have a nice tactile feel, their functions are well described and intuitive, and the learning curve for new users is fast and easy to maneuver. Where the MFD sometimes falls short is in the details. The box provides a truly excellent
general picture of a pilot’s immediate environment but is sometimes weak sharing the associated
details. Despite the easy and intuitive nature of the buttons, it still takes a lot of extra effort to
extract the more precise information often desired. The information chain is sometimes not well
linked to where it would be most quickly and directly leveraged and often must be sifted by the
pilot to uncover what is needed. It is in this corner of its desired functionality that the EX5000
has the most to gain and greatest ability to improve the elegance of its design.

Lastly, it is important to recognize that this evaluation covered only a very small portion
of the EX5000’s broad range of capabilities. The evaluation was able to highlight both strengths
and weaknesses of the device but in no way comprehensively tested other and perhaps more
important human factors issues. Further analysis and extrapolation of the test data may be useful
to further isolate areas of concern and provide better recommendations. Any conclusions or
recommendations included herein probably deserve equal scrutiny in a dynamic environment
before significant design changes are made. Returning back to Professor Crawley’s belief in the
importance of elegance in defining good systems engineering, my final conclusion would be that
the EX5000C MFD has certain simple elegance that will become much richer with age.
Appendices

Appendix A: MFD Displayed Flight Plans

Flight Plan B
Flight Plan C
Flight Plan D
Flight Plan E
Appendix B  Evaluator Crib Sheets

Flight Plan A

Familiarization Directions- Flight Plan A

**Subject:**

**Start Time:**

1. Begin on Map page and describe all items, icons, and functions on the page.
2. Direct user to the “Setup” page and show how to manipulate the data blocks. The default setting will be as follows:

<table>
<thead>
<tr>
<th>Default Data Block Settings</th>
</tr>
</thead>
<tbody>
<tr>
<td>TO WPT + ETE</td>
</tr>
<tr>
<td>TO WPT + ETE</td>
</tr>
<tr>
<td>NEXT WPT</td>
</tr>
<tr>
<td>NEXT WPT</td>
</tr>
<tr>
<td>NRST APRT</td>
</tr>
<tr>
<td>NRST APRT</td>
</tr>
<tr>
<td>LAT/LON</td>
</tr>
<tr>
<td>LAT/LON</td>
</tr>
<tr>
<td>ALT</td>
</tr>
<tr>
<td>TAS</td>
</tr>
<tr>
<td>GROUND SPEED</td>
</tr>
<tr>
<td>LOCAL TIME</td>
</tr>
</tbody>
</table>

3. Direct the user to the “Setup” page and explain in detail the Airport Filter and Declutter settings pages accessible from here.
4. Direct the user to the “Nrst” page and explain the nearest Airport/Navaid functions, features, and options on this page.
5. Direct the user to the “Trip” page and explain the functions and features on this page.
6. Describe all map elements while in flight to ensure the user becomes familiar with all of the map features available. Explain the default settings for the “Airport Filter Setup” (Figure 6.2) as well as the “Declutter Setup- VFR Default” settings for the map. The VFR Defaults modified as seen in (Figure 6.3) will be used during the familiarization flight and all subsequent flights. Specifically, “Class B/C Airspace”, “High Obstacles”, and “Low Obstacles” will be tuned “On” with the “Label” Display box checked.
7. Brief the subject on the upcoming proposed flight plans. All flight plans are to be planned as VFR flights. The aircraft will be have a proposed airspeed of 100 Kts with negligible wind and will be flying at 1500ft AGL or below as appropriate. Ask subject to answer the following questions using only the map or MFD as prescribed in the counter-balancing matrix.

**End Time:**

![Diagram](image-url)
## Flight Plan A

**Subject:**

**Start Time:**

<table>
<thead>
<tr>
<th>MFD</th>
<th>Sectional</th>
<th>Actual</th>
<th>Start Time</th>
<th>End Time</th>
<th>Answer</th>
<th>Subject Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>What is the Tower Frequency at Olympia Airport (KOLM)?</td>
<td>124.4</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>2.</td>
<td>What type of special use airspace is located immediately southwest of the first leg of flight of Gray Army Airfield (KGRF)?</td>
<td>Restricted</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td>What is the floor height of the Class B airspace over Gray AAF (KGRF)?</td>
<td>6000 ft MSL</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>4.</td>
<td>What is the general runway orientation at Seattle-Tacoma International Airport (KSEA)?</td>
<td>North-South</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.</td>
<td>What is the elevation of the runway at Seattle-Tacoma International Airport (KSEA)?</td>
<td>429 ft MSL</td>
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<tr>
<td>6.</td>
<td>How far is Renton Municipal Airport (KRNST) from Seattle-Tacoma International Airport?</td>
<td>4.6 nm</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7.</td>
<td>What is the length of the leg from Seattle-Tacoma International (KSEA) to Snohomish County Airport (KPAE)?</td>
<td>27.6 nm</td>
<td></td>
<td></td>
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<tr>
<td>8.</td>
<td>What is the frequency of the Renton VOR?</td>
<td>353</td>
<td></td>
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</tr>
<tr>
<td>9.</td>
<td>What is the height of the tallest obstacle within 10 nm of the proposed track from Seattle-Tacoma International Airport (KSEA) to Snohomish County Airport (KPAE)?</td>
<td>1071 ft MSL</td>
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**End Time:**

**Subject:**

**Start Time:**

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<th>End Time</th>
<th>Answer</th>
<th>Subject Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>What is the runway elevation at Olympia Airport (KOLM)?</td>
<td>206 ft MSL</td>
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<tr>
<td>2.</td>
<td>What type of controlled airspace surrounds Olympia Airport (KOLM)?</td>
<td>Class D</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>3.</td>
<td>What is the length of the leg between Olympia Airport (KOLM) and Seattle-Tacoma International Airport (KSEA)?</td>
<td>37.6 nm</td>
<td></td>
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<tr>
<td>4.</td>
<td>What is the VOR frequency of the VOR/AC at Seattle-Tacoma International Airport (KSEA)?</td>
<td>116.6</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>5.</td>
<td>What is the control tower frequency at Seattle-Tacoma International Airport (KSEA)?</td>
<td>116.6</td>
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</tr>
<tr>
<td>6.</td>
<td>If you were told to divert to NAS Whidbey Island (KNUW) from Snohomish County (KPAE) how long would it take you to arrive at NAS Whidbey traveling at 100 Kts?</td>
<td>18 min</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>7.</td>
<td>Estimate the distance from Snohomish County Airport (KPAE) to the nearest edge of the restricted airspace located south of NAS Whidbey Island (KNUW)?</td>
<td>12 nm</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>8.</td>
<td>What is the floor height of the Class B airspace over Snohomish County Airport (KPAE)?</td>
<td>3000 ft MSL</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9.</td>
<td>What is the name of the first airport located due East of Snohomish County Airport (KPAE)?</td>
<td>Harvey (KS43)</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tbody>
</table>

**End Time:**

82
Flight Plan B

Subject: __________

Waypoint 1: Deland Municipal (KDED)
Waypoint 2: Orlando Sanford (KSFB)
Waypoint 3: Ormond Beach (KOMN)
Alternate Destination: Flagler County (X47)

Start Time: __________

<table>
<thead>
<tr>
<th>MFD</th>
<th>Actual</th>
<th>Start Time</th>
<th>End Time</th>
<th>Answer</th>
<th>Subject Comments</th>
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<tbody>
<tr>
<td>A)</td>
<td>State the full name of the departure airport.</td>
<td>Deland-Taylor</td>
<td></td>
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</tr>
<tr>
<td>B)</td>
<td>State the course of the first leg of flight</td>
<td>170</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>C)</td>
<td>State the common traffic advisory frequency (CTAF) you would use for takeoff at Deland-Taylor (KDED).</td>
<td>123.075</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D)</td>
<td>State the type of special use airspace located about 15 nm west of Deland-Taylor Airport (KDED).</td>
<td>Restricted</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>E)</td>
<td>State the height of the highest obstacle within 10nm of the first leg of flight.</td>
<td>1749 ft MSL</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F)</td>
<td>State the full name of the airport centered on the Class C airspace on the second leg of the flight.</td>
<td>Daytona Beach International</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>G)</td>
<td>Estimate of how long would it take to divert to Flagler County Airport (X47) from Ormond Beach (KOMN) if you were traveling at 100 knots?</td>
<td>6.7</td>
<td></td>
<td></td>
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<tr>
<td>H)</td>
<td>State the frequency of the NDB closest to Daytona International Airport (KDAB).</td>
<td>417</td>
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End Time: __________

Start Time: __________

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<th>End Time</th>
<th>Answer</th>
<th>Subject Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>I)</td>
<td>State the distance from Waypoint 2 to Waypoint 3.</td>
<td>30.3</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>J)</td>
<td>State the ceiling altitude of the first Class B airspace you would encounter as you approach Orlando Sanford (KSFB) from Waypoint 1.</td>
<td>10000 ft MSL</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>K)</td>
<td>State the general orientation of a majority of the runway(s) at Orlando Sanford (KSFB).</td>
<td>E-W</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>L)</td>
<td>State the altitude of the tallest obstacle within the class D airspace at Orlando Sanford (KSFB).</td>
<td>355 ft MSL</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>M)</td>
<td>State the frequency of the control tower at Orlando Sanford (KSFB).</td>
<td>129.3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N)</td>
<td>State the floor altitude of the last Class B airspace shelf you will fly under in route to Waypoint 3.</td>
<td>3000 ft MSL</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>O)</td>
<td>State the course you would take to divert to Flagler Co. (X47) from Ormond Beach (KOMN) if directed to do so.</td>
<td>026</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>P)</td>
<td>State the runway elevation at Ormond Beach (KOMN).</td>
<td>28.9 ft MSL</td>
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</table>

End Time: __________
Flight Plan C

Subject: ____________________________________________

Waypoint 1: Herlong Airport (23J) OR (KHEG)
Waypoint 3: Jacksonville International (KJAX)
Waypoint 3: Fernandina Beach (55J)
Alternate Destination: St. Mary's Airport (4J6)

Start Time: ____________________________

<table>
<thead>
<tr>
<th>MFD</th>
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<th>Start Time</th>
<th>End Time</th>
<th>Answer</th>
<th>Subject Comments</th>
<th>Notes</th>
</tr>
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<tbody>
<tr>
<td>A)</td>
<td>State the altitude of the departure airport (23J) or (KHEG).</td>
<td>23J MSL</td>
<td>87 ft MSL</td>
<td>87 ft MSL</td>
<td></td>
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</tr>
<tr>
<td>B)</td>
<td>State the length of the first leg of the flight.</td>
<td>14.3</td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>C)</td>
<td>State the course to fly direct to your destination airport (55J) from Herlong (23J).</td>
<td></td>
<td>080</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D)</td>
<td>State the frequency for Automated Weather Observation Station (AWOS) at Herlong Airport (23J).</td>
<td>119.275</td>
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</tr>
<tr>
<td>E)</td>
<td>State the kind of controlled airspace centered on NAS Jacksonville (KNIP).</td>
<td>Class C</td>
<td>119.3</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F)</td>
<td>State the control tower frequency for Jacksonville International (KJAX).</td>
<td>122.7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>G)</td>
<td>State the ceiling altitude of the outer ring of Class C airspace at centered on Jacksonville International (KJAX).</td>
<td>5000 ft MSL</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>H)</td>
<td>State the general runway orientation at Jacksonville International.</td>
<td>NW-SE, SW-NE</td>
<td></td>
<td></td>
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End Time: ____________________________

Start Time: ____________________________

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<th>Subject Comments</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>I)</td>
<td>State the name of the NDB navigation aid located approximately 7 nm west-southwest of Jacksonville International (KJAX).</td>
<td>Ches</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>J)</td>
<td>State the CTAF frequency at Fernandina Beach (55J).</td>
<td>122.7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>K)</td>
<td>State the altitude of the tallest obstacle within 5nm of the 2nd leg of the flight.</td>
<td>5000 ft MSL</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>L)</td>
<td>State the distance between Waypoint 2 and Waypoint 3.</td>
<td>14.8</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>M)</td>
<td>State floor altitude of the outer shelf of Class C airspace you will fly out of from Waypoint 2 to Waypoint 3.</td>
<td>12000 ft MSL</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N)</td>
<td>State the course to your divert at St. Mary's (4J6) from Fernandina Beach (55J).</td>
<td>050</td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>O)</td>
<td>State the runway length at St Mary's (4J6).</td>
<td>584</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>P)</td>
<td>Estimate the time it will take to divert to St Mary's (4J6) from Fernandina Beach (55J) if you fly at 100kts with no wind.</td>
<td>5.84 minutes</td>
<td></td>
<td></td>
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End Time: ____________________________
# Flight Plan D

**Subject:**

**Waypoint 1:** Orlando Country (X04)  
**Waypoint 2:** Kissimmee Muni. (KISM)  
**Waypoint 3:** Merritt Island (KCOI)  
**Alternate:** Space Coast Regional (KTIX)

## Start Time:

<table>
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<tr>
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<th>End Time</th>
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<th>Subject Comments</th>
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</thead>
<tbody>
<tr>
<td>A)</td>
<td>State the common traffic advisory frequency at the departure airport.</td>
<td>123.00</td>
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<td></td>
</tr>
<tr>
<td>B)</td>
<td>State the type of airspace Orlando Country Airport (X04) is located under.</td>
<td>Class B</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C)</td>
<td>State the course of the first leg of the flight.</td>
<td>163</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D)</td>
<td>State the distance at your closest point of approach to Orlando Executive Airport (ORL) during the first leg.</td>
<td>9.1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>E)</td>
<td>State the floor altitude of the Class B airspace located over Kissimmee Municipal Airport (KISM).</td>
<td>2000 ft MSL</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F)</td>
<td>State the control tower frequency at Kissimmee Airport (KISM).</td>
<td>124.45</td>
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<td></td>
</tr>
<tr>
<td>G)</td>
<td>Estimate the distance from Kissimmee Airport (KISM) to Orlando International Airport (KMCO).</td>
<td>10.5</td>
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<tr>
<td>H)</td>
<td>State the general runway orientation of the runways at Orlando International (KMCO).</td>
<td>N-</td>
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## End Time:

**Start Time:**

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<th>End Time</th>
<th>Answer</th>
<th>Subject Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>I)</td>
<td>State the VOR frequency of the Orlando VORTAC (ORL) located approximately 16 nm northeast Kissimmee Airport (KISM).</td>
<td>132.2</td>
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</tr>
<tr>
<td>J)</td>
<td>State the distance between Waypoint 2 and Waypoint 3</td>
<td>8.9</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>K)</td>
<td>State the height of the tallest obstacle within 5 nm of the course between Waypoint 2 and Waypoint 3.</td>
<td>1048 ft MSL</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>L)</td>
<td>State the frequency for receiving weather information about Kissimmee Airport (KISM).</td>
<td>126.375</td>
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</tr>
<tr>
<td>M)</td>
<td>State the floor altitude of the last shelf of Class B airspace you fly through on the way to Merritt Island (KCOI).</td>
<td>8000 ft MSL</td>
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</tr>
<tr>
<td>N)</td>
<td>State the airport elevation for Merritt Island Airport (KCOI).</td>
<td>79 ft MSL</td>
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</tr>
<tr>
<td>P)</td>
<td>State the type of airspace surrounding your alternate, Space Coast Regional Airport (KTIX).</td>
<td>NW-SE</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Q)</td>
<td>State the general runway orientation for Merritt Island Airport (KCOI).</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R)</td>
<td>Estimate the time it would take to travel to the alternate, Space Coast Regional (KTIX) from Merritt Island airport (KCOI) at 100 kts.</td>
<td>7.2</td>
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## End Time:
**Flight Plan E**

Subject: 

Waypoint 1: Portland International (KPDX)
Waypoint 2: Portland-Hillsboro (KHIO)
Waypoint 3: Portland-Troutdale (KTTD)
Alternate Airport: Grove (IWI)

Start Time: 

<table>
<thead>
<tr>
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<th>MFD</th>
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<th>End Time</th>
<th>Answer</th>
<th>Subject Comments</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>A)</td>
<td>State runway length at Portland International (KPDX).</td>
<td>11000 ft</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B)</td>
<td>State the approximate time to travel the first leg of the flight plan at 100 knots.</td>
<td>9.1 min</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C)</td>
<td>State the ceiling altitude of the outer ring of the Class C airspace centered on Portland International (KPDX).</td>
<td>4300 ft MSL</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D)</td>
<td>State the altitude of the highest obstacle within 5 nm of the first leg of the flight.</td>
<td>2248 ft MSL</td>
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<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>E)</td>
<td>State the control tower frequency for the Portland-Hillsboro (KHIO) Airport.</td>
<td>119.3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>F)</td>
<td>State the bearing from Portland-Hillsboro (KHIO) to the Newburg VORTAC (UBG) located approximately 11 nm to the south of Hillsboro.</td>
<td>000° True</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>G)</td>
<td>State the course for the second leg of the flight.</td>
<td>088° True</td>
<td></td>
<td></td>
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End Time: 

<table>
<thead>
<tr>
<th></th>
<th>MFD</th>
<th>Sectional</th>
<th>Actual</th>
<th>Start Time</th>
<th>End Time</th>
<th>Answer</th>
<th>Subject Comments</th>
<th>Notes</th>
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<tbody>
<tr>
<td>H)</td>
<td>State the floor altitude of the first Class C shelf the proposed track will fly through on the second leg.</td>
<td>7200 ft MSL</td>
<td></td>
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<tr>
<td>I)</td>
<td>State the distance between Waypoint 2 and Waypoint 3.</td>
<td>23.1 nmi</td>
<td></td>
<td></td>
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<tr>
<td>J)</td>
<td>State the course you would fly to proceed direct from Waypoint 2 direct to your alternate at Grove Airport (IWI).</td>
<td>077°</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>K)</td>
<td>State the type of controlled airspace centered on Portland-Troutdale (KTTD).</td>
<td>Class D</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>L)</td>
<td>State the altitude of the destination airfield Portland-Troutdale (KTTD).</td>
<td>1800 ft MSL</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>M)</td>
<td>State the general runway orientation using cardinal directions of the alternate, Grove Airport (IWI).</td>
<td>060°</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>N)</td>
<td>State the height of the tallest obstacle within the Class D airspace at Portland-Troutdale Airport (KTTD).</td>
<td>2944 ft MSL</td>
<td></td>
<td></td>
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<td></td>
<td></td>
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</tr>
<tr>
<td>O)</td>
<td>State the number of airfield(s) with services that are located within the Portland International (KPDOX) Class C controlled airspace.</td>
<td>8</td>
<td></td>
<td></td>
<td></td>
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End Time:
Appendix C: Subjective Evaluations

Flight Plan B

Subject: 1

Instructions: Using the Attached modified-Cooper Harper Scale, please score the following tasks. Space is available for comments as well.

1. Identify towers and other similar hazards to navigation. -MFD  Score: 2

*In highly dense areas, altitude of obstacle can be confused with other obstacle.*

2. Identify towers and other similar hazards to navigation. -Sectional  Score: 2

3. Locate airport communication frequencies - MFD  Score: 2

*It's easy to find nearest frequencies of nearby airport; but I would like a way to control what I see, i.e., a particular airport further out → cursor control.*

4. Locate airport communication frequencies - Sectional  Score: 2

5. Estimate distance- Both  Score: MFD- 5, SECT-2

*On MFD it is difficult to measure between 2 pts. A measure function would be great.*

Flight Plan C

Subject: 1

Instructions: Using the Attached modified-Cooper Harper Scale, please score the following tasks. Space is available for comments as well.

1. Identify controlled airspace restrictions. – MFD  Score: 3

*Good, except some airspace has the restrictions on the ring confusing which ring it should be in.*

2. Identify controlled airspace restrictions. – Sectional  Score: 2

3. Locate available navigation aids and/or their frequencies- MFD  Score: 3

*As long as they appear on the nearest page.*

4. Locate available navigation aids and/or their frequencies – Sect.  Score: 2
Subjective Questionnaire

Part I: MFD User Interface
Administer once after completion of flight Plans B and C.

1. What are the best features of the MFD user interface?
- Available functions are very easy to see
- Gives a handy overview of what is close by.
- Lots of info displayed constantly.

2. What are the worst features of the MFD user interface?
- Not being able to see info about something off of NRST page.
- Need ability to measure course & dist between 2 user selected points.
- Does not show courses between waypoints on FLT Plan
- Range selection knob rotation seems backwards.

3. What specific things would you like to see different?
- See 2.

Flight Plan D

Instructions: Using the Attached modified-Cooper Harper Scale, please score the following tasks. Space is available for comments as well.

1. Ability of user to read and interpret available information. – MFD
   - Score: 3
   Except Class B altitudes. Bad.
2. Assessing time/distance from the aircraft to map specified objects. – MFD

Score: 2

As long as it’s on NRST Page.

3. Identifying potential hazards to flight, e.g. obstacles, airspace, etc. – MFD

Score: 2

4. Finding useful information at approach, destination, or along flight path. – MFD

Score: 5

Has to be on NRST page.

Flight Plan E

Subject: 1

Instructions: Using the Attached modified-Cooper Harper Scale, please score the following tasks. Space is available for comments as well.

1. Ability of user to read and interpret available information. – Sectional

Score: 3

2. Assessing time/distance from the aircraft to map specified objects. – Sectional

Score: 3

Have to measure

3. Identifying potential hazards to flight, e.g. obstacles, airspace, etc. – Sectional

Score: 2

4. Finding useful information at approach, destination, or along flight path. – Sectional

Score: 1

Subjective Questionnaire

Subject: 1

Part II: MFD Map and Information Content

Administer once after completion of Flight Plans D and E
1. What do you like the most about the manner information is displayed and the available content?

    Quick glance gives useful overview info.

2. What do you like the least about the manner information is displayed and the available content?

    - Airspace altitudes are bad
    - Can’t interrogate info that is not on NRST page

3. What would you like to see different about the manner information is displayed and the available content?

    - Airspace altitudes are wrong/useless.

4. Additional Comments on any issue not already addressed can be written here. Thanks for your time and consideration.

    - Numerous errors between MFD/Sectional
Flight Plan B

Subject: 2

Instructions: Using the Attached modified-Cooper Harper Scale, please score the following tasks. Space is available for comments as well.

1. Identify towers and other similar hazards to navigation. -MFD Score: 2
2. Identify towers and other similar hazards to navigation. -Sect. Score: 2
3. Locate airport communication frequencies- MFD Score: 5 or 10

From Map, I choose an airport, memorize the identifier, go to the NRST page, find the identifier (which is a little difficult), scroll to the airport and hit INFO.

10. If an airport is far away and not accessible through the NRST page, I can’t get the info. It would be nice to be able to click an airport right on the map!!!

4. Locate airport communication frequencies - Sectional Score: 2 or 10

2. Finding frequencies- I know how to do that.

10. Only tow or CTAF is shown- no Grnd, APPR, etc.

5. Estimate distance- MFD Score: 2
6. Estimate Distance- Sectional Score: 2

Flight Plan C

Subject: 2

Instructions: Using the Attached modified-Cooper Harper Scale, please score the following tasks. Space is available for comments as well.

1. Identify controlled airspace restrictions. – MFD Score: 8

Incorrect airspace floor in outer ring of JAX Class C

2. Identify controlled airspace restrictions. – Sectional Score: 1

3. Locate available navigation aids and/or their frequencies- MFD Score: 3

Several steps (like Flight Plan B, #3) is required to get freq. Would like frequencies on the map.
4. Locate available navigation aids and/or their frequencies – Sect. Score: 1
5. Estimate course- MFD Score: 2
6. Estimate Course- Sectional Score: 2

Subjective Questionnaire Subject: 2

Part I: MFD User Interface
Administer once after completion of flight Plans B and C.

1. What are the best features of the MFD user interface?
   Customizable features
   Lots of info available

2. What are the worst features of the MFD user interface?
   Info often hard to get to.

3. What specific things would you like to see different?
   I’d like to see a way to get to APT info other than the NRST page. While we can debate about the joystick/pointer vs. alphanumeric entry, this interface has eliminated both!

Flight Plan D Subject: 2

Instructions: Using the Attached modified-Cooper Harper Scale, please score the following tasks. Space is available for comments as well.

1. Ability of user to read and interpret available information. – MFD Score: 2
2. Assessing time/distance from the aircraft to map specified objects. – MFD Score: 2
3. Identifying potential hazards to flight, e.g. obstacles, airspace, etc. – MFD Score: 2
4. Finding useful information at approach, destination, or along flight path. – MFD Score: 4
Flight Plan E

Instructions: Using the Attached modified-Cooper Harper Scale, please score the following tasks. Space is available for comments as well.

1. Ability of user to read and interpret available information. – Sectional
   Score: 2

2. Assessing time/distance from the aircraft to map specified objects. – Sectional
   Score: 2

3. Identifying potential hazards to flight, e.g. obstacles, airspace, etc. – Sectional
   Score: 2

4. Finding useful information at approach, destination, or along flight path. – Sectional
   Score: 2

Subjective Questionnaire

Part II: MFD Map and Information Content
Administer once after completion of Flight Plans D and E

1. What do you like the most about the manner information is displayed and the available content?
   I like the details that are graphic and don’t require me to think in numbers.

2. What do you like the least about the manner information is displayed and the available content?
   Some runway pictures not available, both on the map and in the airport info page.

3. What would you like to see different about the manner information is displayed and the available content?
   More graphical, more consistent.

4. Additional Comments on any issue not already addressed can be written here. Thanks for your time and consideration.
   ?- What’s the difference between North Up and Center?
   - The Range pop-up text should be right next to the range on the Compass Rose.
   - It is hard to jump back an forth.
- Why don't all airports show the runway orientation in MAP? (Like sectionals so)- try 1W1
-I'd like to see the VOR labels include frequencies- its a many step process to get that info- I won't use the MFD to do it!
-Airspace floor and ceiling altitudes should:
  1. Always be visible at any range
  2. Be correct!!- See floor of JAX Class C
-Only getting airport info through the NRST page stinks. Try one or more of:
  1. Alphanumeric input
  2. Cursor control to do it graphically on the map
It takes a lot of headwork to get the info. See Plan B, comment 3.
-When many frequencies exist, MFD is no help.
  1. At JAX, the sectional shows 2 freqs. The MFD shows a dozen! How do I choose?
  2. At SFB, there are two tower freqs. I assume there's a north and South, or something like that. The MFD should have that info, or it becomes a collection of a lot of data that is worthless.
Flight Plan B

Instructions: Using the Attached modified-Cooper Harper Scale, please score the following tasks. Space is available for comments as well.

1. Identify towers and other similar hazards to navigation. -MFD
   Difficult to read.
   Frequently overlap at strategic map scales.
   Score: 7

2. Identify towers and other similar hazards to navigation. –Sect.
   Score: 3

3. Locate airport communication frequencies- MFD
   Score: 2

4. Locate airport communication frequencies - Sectional
   Score: 3

5. Estimate distance- Both
   Score: 3

6. Estimate Distance- Sectional
   Score: 4

Flight Plan C

Instructions: Using the Attached modified-Cooper Harper Scale, please score the following tasks. Space is available for comments as well.

1. Identify controlled airspace restrictions. –MFD
   Sector altitudes sometimes difficult to find (more so in previous cases)
   Score: 3

2. Identify controlled airspace restrictions. – Sectional
   Ditto
   Score: 3

3. Locate available navigation aids and/or their frequencies- MFD
   (Within are covered by NRST- else 10)
   Score: 2

4. Locate available navigation aids and/or their frequencies – Sect.
   Association between data and Navaid sometimes ambiguous
   Score: 3

5. Estimate course- MFD
   Score: 2

6. Estimate Course- Sectional
   Score: 2

Subjective Questionnaire

Part I: MFD User Interface
Administer once after completion of flight Plans B and C.
1. What are the best features of the MFD user interface?
   Rapid page access
   Lots of room for map/data even with button and knob legends or

2. What are the worst features of the MFD user interface?
   Exclusive reliance on NRST for info access - Finding items in list tedious and
distracting - Pick waypoints from flightplan!

3. What specific things would you like to see different?

Flight Plan D

Instructions: Using the Attached modified-Cooper Harper Scale, please score the following tasks. Space is available for comments as well.

1. Ability of user to read and interpret available information. – MFD
   Class B sector altitudes often missing or positioned incorrectly.
   Score: 10

2. Assessing time/distance from the aircraft to map specified objects. – MFD
   Score: 3

3. Identifying potential hazards to flight, e.g. obstacles, airspace, etc. – MFD
   Score: 4

4. Finding useful information at approach, destination, or along flight path. – MFD
   Score: 2

Flight Plan E

Instructions: Using the Attached modified-Cooper Harper Scale, please score the following tasks. Space is available for comments as well.

1. Ability of user to read and interpret available information. – Sectional
   Score: 2

2. Assessing time/distance from the aircraft to map specified objects. – Sectional
   Score: 2

3. Identifying potential hazards to flight, e.g. obstacles, airspace, etc. – Sectional
   Score: 2

4. Finding useful information at approach, destination, or along flight path. – Sect
   Score: 2

Subjective Questionnaire

Part II: MFD Map and Information Content
Administer once after completion of Flight Plans D and E
1. What do you like the most about the manner information is displayed and the available content?

_With the exception of obstacle, the map is clean and readable. (This might change if all the Class B altitudes were actually depicted!)_

2. What do you like the least about the manner information is displayed and the available content?

_Obstacles (In General)_
_Class B Altitudes._

3. What would you like to see different about the manner information is displayed and the available content?

_Sort by name/Sort by ID in NRST_
_Pick flightplan waypoints for INFO_
_Add leg length on trip page._

4. Additional Comments on any issue not already addressed can be written here. Thanks for your time and consideration.
Flight Plan B

Instructions: Using the Attached modified-Cooper Harper Scale, please score the following tasks. Space is available for comments as well.

1. **Identify towers and other similar hazards to navigation.** - MFD  
   - Need ability to filter obstructions within prescribed distance from flight path (i.e. 20 nm) and own aircraft (bubble). Alert when approaching within 5 nm or so, more intense alert if within 2000 ft of obstacle.  
   - Can't scroll off of own aircraft centered display to examine obstacles on flight path.  
   - Still better than sectional  
   **Score: 3**

2. **Identify towers and other similar hazards to navigation.** - Sect.  
   - Sectional is cluttered, requiring more thorough preflight planning. Leaves room for error in contingency situations (altered flight path, divert, emergency)  
   **Score: 5**

3. **Locate airport communication frequencies.** - MFD  
   - Complete list of freqs, but should have option of displaying freqs on map for local control authorities (i.e. if VFR flight following)  
   **Score: 3**

4. **Locate airport communication frequencies** - Sectional  
   **Score: 4**

5. **Estimate distance.** - MFD  
   - Need distance displays from present position to points, as well as from point to point (not just cumulative distance as displayed on TRIP display)  
   **Score: 6**

6. **Estimate Distance** - Sectional  
   - Latitude ticks and a pencil provide more accurate distance measure than MFD for points not on current flight leg.  
   **Score: 4**

Flight Plan C

Instructions: Using the Attached modified-Cooper Harper Scale, please score the following tasks. Space is available for comments as well.

1. **Identify controlled airspace restrictions.** - MFD  
   **Score: 2**

2. **Identify controlled airspace restrictions.** - Sectional  
   **Score: 3**

3. **Locate available navigation aids and/or their frequencies.** - MFD  
   - Display is better on mFD (more readable), but not as intuitive if one is looking for freqs. Relative to flight path.  
   **Score: 3**
- Would be nice to be able to click on an airport to bring up the freqs while still on the map display.

4. Locate available navigation aids and/or their frequencies — Sect. Score: 3
5. Estimate course—MFD Score: 3
6. Estimate Course—Sectional Score: 3

Subjective Questionnaire

Part I: MFD User Interface
Administer once after completion of flight Plans B and C.

1. What are the best features of the MFD user interface?
   - Raster selection for options
   - Tactile characteristics are nice (positive feedback that a selection has been made / appropriate click)
   - Backlit buttons nice.

2. What are the worst features of the MFD user interface?
   Buttons could be slightly larger w/ more defined indentation surrounding them. (Guide finger to button)
   Backlight color should be red instead of green for maintaining night vision.
3. What specific things would you like to see different?

Flight Plan D

Subject: 4

Instructions: Using the Attached modified-Cooper Harper Scale, please score the following tasks. Space is available for comments as well.

1. Ability of user to read and interpret available information. – MFD

   Score: 3

2. Assessing time/distance from the aircraft to map specified objects. – MFD

   Score: 3

3. Identifying potential hazards to flight, e.g. obstacles, airspace, etc. – MFD

   Score: 3

4. Finding useful information at approach, destination, or along flight path. – MFD

   Score: 3

   - An ability to hook point information while on the map display would be helpful. (Touch screen or trackball?)
Flight Plan E

Instructions: Using the Attached modified-Cooper Harper Scale, please score the following tasks. Space is available for comments as well.

1. Ability of user to read and interpret available information. – Sectional

   Score: 4

2. Assessing time/distance from the aircraft to map specified objects. – Sectional

   Score: 3

3. Identifying potential hazards to flight, e.g. obstacles, airspace, etc. – Sectional

   Score: 4

4. Finding useful information at approach, destination, or along flight path. – Sectional

   Score: 3

Subjective Questionnaire

Part II: **MFD Map and Information Content**

Administer once after completion of Flight Plans D and E

1. What do you like the most about the manner information is displayed and the available content?
   - Map display w/ compass rose and range selection
   - Airspace markings
   - Airport labels

2. What do you like the least about the manner information is displayed and the available content?
   - Clutter can be high (esp. w/ obstacles)
     - Recommend offering user0defined Declutter layering (with default show threat obstacles, restricted airspace, etc.)
     - Waypoint information on TRIP page is very limited.
   - Should have displays for all legs of flight, brg and dist between each, with cumulative trip distance as well as brg/dst/time from present position to selected point (in case of an enroute modification to flight plan)
3. What would you like to see different about the manner information is displayed and the available content?
   -TRIP page should be more useful/informative.

4. Additional Comments on any issue not already addressed can be written here. Thanks for your time and consideration.
Flight Plan B

Subject: 5

Instructions: Using the Attached modified-Cooper Harper Scale, please score the following tasks. Space is available for comments as well.

1. Identify towers and other similar hazards to navigation. -MFD
   Time in Sim + Flt Hrs = Familiarity ⇒ Decreased Response Time
   (i.e., declutter button not used in test.)
   Score: 5

2. Identify towers and other similar hazards to navigation. –Sect.
   No ability to declutter
   Score: 4

3. Locate airport communication frequencies- MFD
   Score: 2

4. Locate airport communication frequencies - Sectional
   Score: 2

5. Estimate distance- MFD
   Score: 3

6. Estimate Distance- Sectional
   Score: 2

Flight Plan C

Subject: 5

Instructions: Using the Attached modified-Cooper Harper Scale, please score the following tasks. Space is available for comments as well.

1. Identify controlled airspace restrictions. – MFD
   Outer ring of Class C can’t by definition be “SFC to 4000” = error in data requires some thought to catch
   Score: 7

2. Identify controlled airspace restrictions. – Sectional
   Score: 3

3. Locate available navigation aids and/or their frequencies- MFD
   Frequency on separate page slows progress.
   Score: 3
4. Locate available navigation aids and/or their frequencies – Sect. 

5. Estimate course—MFD 

6. Estimate Course—Sectional 

Score: 2

Score: 2

Score: 4

Subjective Questionnaire

Part I: MFD User Interface

Administer once after completion of flight Plans B and C.

1. What are the best features of the MFD user interface?
   - Hardware (buttons, knobs, etc) easy to use, feel good (positive feedback when pushed, etc.)
   - Display orientation also good: much useful info at one time and selectability/set up is good.
   - Classification and amount of data very useful; builds user confidence
   - Declutter is good.

2. What are the worst features of the MFD user interface?
   - Depending on use (high vs. low ALT, IFR vs. VFR, fixed vs. RTR wing), some info less convenient than other info.

3. What specific things would you like to see different?
   - No lines of Longitude (sic) on display= difficult to visually estimate some dist.

Flight Plan D

Instructions: Using the Attached modified-Cooper Harper Scale, please score the following tasks. Space is available for comments as well.

1. Ability of user to read and interpret available information. – MFD 

Score: 3

2. Assessing time/distance from the aircraft to map specified objects. – MFD 

Score: 5

Again, ability to est distance from pts not at ctr of screen challenged by lack of extra scale. Should have method for selecting AFLD to CTR screen for obstacles, time/dist, etc.
3. Identifying potential hazards to flight, e.g. obstacles, airspace, etc. – MFD

Score: 2

4. Finding useful information at approach, destination, or along flight path. – MFD

Score: 2

Flight Plan E

Subject: 5

Instructions: Using the Attached modified-Cooper Harper Scale, please score the following tasks. Space is available for comments as well.

1. Ability of user to read and interpret available information. – Sectional

Score: 2

2. Assessing time/distance from the aircraft to map specified objects. – Sectional

Score: 2

3. Identifying potential hazards to flight, e.g. obstacles, airspace, etc. – Sectional

Score: 2

4. Finding useful information at approach, destination, or along flight path. – Sectional

Score: 2

Score based on familiarity w/ sect vs. lack of familiarity w/ MFD

Subjective Questionnaire

Subject: 5

Part II: MFD Map and Information Content

Administer once after completion of Flight Plans D and E

1. What do you like the most about the manner information is displayed and the available content?
   - Customize displays
   - Amount of info
   - Decreases number of references needed (approach charts, sectionals, etc, etc.)
2. What do you like the least about the manner information is displayed and the available content?
   - Time/Dirt/Hdg Info
   - Unable to select new reference points for data (Other AFLDS, etc)

3. What would you like to see different about the manner information is displayed and the available content?
   - Select AFLDS by Alpha-numeric ID for T/D/H, etc.
   - LONG. lines on display for Ref

4. Additional Comments on any issue not already addressed can be written here. Thanks for your time and consideration.
   - Ability to familiarize w/ equipment would increase effectiveness and G response time. In other words, goes w/o saying that added time on system will improve efficiency.
   - Ability to see different classes of info on one screen is good for reference ("Where are my alternate?") but then can’t pick one AFLD easily and know extra info other than ref data.
Flight Plan B

Instructions: Using the Attached modified-Cooper Harper Scale, please score the following tasks. Space is available for comments as well.

1. Identify towers and other similar hazards to navigation. -MFD   Score: 3
2. Identify towers and other similar hazards to navigation. –Sect.   Score: 4
3. Locate airport communication frequencies- MFD               Score: 2
4. Locate airport communication frequencies - Sectional        Score: 1
5. Estimate distance- MFD                                     Score: 3
6. Estimate Distance- Sectional                               Score: 3

Flight Plan C

Instructions: Using the Attached modified-Cooper Harper Scale, please score the following tasks. Space is available for comments as well.

1. Identify controlled airspace restrictions. – MFD    Score: 1
2. Identify controlled airspace restrictions. – Sectional  Score: 1
3. Locate available navigation aids and/or their frequencies- MFD   Score: 2
4. Locate available navigation aids and/or their frequencies – Sect. Score: 1
5. Estimate course- MFD                                       Score: 2
6. Estimate Course- Sectional                                 Score: 2

Subjective Questionnaire

Part I: MFD User Interface
Administer once after completion of flight Plans B and C.

1. What are the best features of the MFD user interface?
   The MFD can be customized during set up to access specific information which is most useful to the pilot. Page is always identified so I can easily determine where I need to move in order to discover the information. Buttons are intuitive and don’t require interpretation to understand the function of the respective button.
2. What are the worst features of the MFD user interface?

When looking for nearest information, especially if in a hurry, a specific airport may be overlooked.

3. What specific things would you like to see different?

In the nearest future, it would be nice if text was (sic) color coded to match towered and non-towered, making them easier to reference and identify.

Flight Plan D

Subject: 6

Instructions: Using the Attached modified-Cooper Harper Scale, please score the following tasks. Space is available for comments as well.

1. Ability of user to read and interpret available information. – MFD Score: 2
2. Assessing time/distance from the aircraft to map specified objects. – MFD Score: 3
3. Identifying potential hazards to flight, e.g. obstacles, airspace, etc. – MFD Score: 2
4. Finding useful information at approach, destination, or along flight path. – MFD Score: 2

Flight Plan E

Subject: 6

Instructions: Using the Attached modified-Cooper Harper Scale, please score the following tasks. Space is available for comments as well.

1. Ability of user to read and interpret available information. – Sectional Score: 2
2. Assessing time/distance from the aircraft to map specified objects. – Sectional Score: 2
3. Identifying potential hazards to flight, e.g. obstacles, airspace, etc. – Sectional Score: 2
4. Finding useful information at approach, destination, or along flight path. – Sectional Score: 2

Subjective Questionnaire

Subject: 6

Part II: MFD Map and Information Content

Administer once after completion of Flight Plans D and E
1. What do you like the most about the manner information is displayed and the available content?
Color coding makes identify airports, obstacles, etc. easy. Showing the waypoint on the flightplan at a larger font highlights those areas. Data blocks are a huge help when calculating important information such as ETA, bearing, and distance.

2. What do you like the least about the manner information is displayed and the available content?
To view the highest obstacles on a particular flightplan, I had to range out to a point where viewing the height of the highest obstacle was difficult. Also some information overlaps which makes it difficult to read.

3. What would you like to see different about the manner information is displayed and the available content?
Add a place in the datablock that interprets the highest obstacle on a flight plan or in a specific range.

4. Additional Comments on any issue not already addressed can be written here. Thanks for your time and consideration.
Flight Plan B

Instructions: Using the Attached modified-Cooper Harper Scale, please score the following tasks. Space is available for comments as well.

1. Identify towers and other similar hazards to navigation. -MFD  
   Score: 2

   For initial exposure, user friendly.

2. Identify towers and other similar hazards to navigation. -Sect.  
   Score: 8

3. Locate airport communication frequencies- MFD  
   “One” touch system very easy to use. This beats fumbling with a map everytime.

4. Locate airport communication frequencies - Sectional  
   Score: 7

5. Estimate distance- MFD  
   Score: 3

   I had to “guess-timate” on the task during the test.

6. Estimate Distance- Sectional  
   Score: 2

   I have been doing this for 12 years- I think with time the MFD would be much easier.

Flight Plan C

Instructions: Using the Attached modified-Cooper Harper Scale, please score the following tasks. Space is available for comments as well.

1. Identify controlled airspace restrictions. – MFD  
   Score: 2

2. Identify controlled airspace restrictions. – Sectional  
   Score: 3

3. Locate available navigation aids and/or their frequencies- MFD  
   Score: 2

4. Locate available navigation aids and/or their frequencies – Sect.  
   Score: 4

5. Estimate course- MFD  
   Score: 3

6. Estimate Course- Sectional  
   Score: 4

Subjective Questionnaire

Part I: MFD User Interface

Administer once after completion of flight Plans B and C.
1. What are the best features of the MFD user interface?
Relatively easy to get the info you need in a timely fashion- (once familiar).

2. What are the worst features of the MFD user interface?
More user feature than MFD, but a lot of info initially thrown at you. Again, familiarity is the key.

3. What specific things would you like to see different?
Nothing specific.

Flight Plan D

Instructions: Using the Attached modified-Cooper Harper Scale, please score the following tasks. Space is available for comments as well.

1. Ability of user to read and interpret available information. – MFD

   Score: 3

Familiarity is the key.

2. Assessing time/distance from the aircraft to map specified objects. – MFD

   Score: 3

3. Identifying potential hazards to flight, e.g. obstacles, airspace, etc. – MFD

   Score: 2

4. Finding useful information at approach, destination, or along flight path. – MFD

   Score: 2

Flight Plan E

Instructions: Using the Attached modified-Cooper Harper Scale, please score the following tasks. Space is available for comments as well.

1. Ability of user to read and interpret available information. – Sectional

   Score: 4

Had some practice.
2. Assessing time/distance from the aircraft to map specified objects. – Sectional
   Score: 5

3. Identifying potential hazards to flight, e.g. obstacles, airspace, etc. – Sectional
   Score: 5

4. Finding useful information at approach, destination, or along flight path. – Sectional
   Score: 4

Subjective Questionnaire

Part II: *MFD Map and Information Content*

Administer once after completion of Flight Plans D and E

1. What do you like the most about the manner information is displayed and the available content?
   *Once you understand the system, info was easy to access.*

2. What do you like the least about the manner information is displayed and the available content?
   *Just have to know where to find it, and cut out the other info.*

3. What would you like to see different about the manner information is displayed and the available content?
   *Perhaps a way to calculate speed/time/distance problems faster.*

4. Additional Comments on any issue not already addressed can be written here. Thanks for your time and consideration.
   As a strict replacement or comparison to VFR sectionals, this is a great product. Again, familiarization is the key.
Flight Plan B

Subject: 8

Instructions: Using the Attached modified-Cooper Harper Scale, please score the following tasks. Space is available for comments as well.

1. Identify towers and other similar hazards to navigation. -MFD Score: 3
2. Identify towers and other similar hazards to navigation. -Sect. Score: 4
3. Locate airport communication frequencies- MFD Score: 4
4. Locate airport communication frequencies - Sectional Score: 2
5. Estimate distance- MFD Score: 5
   Don’t do this with MFD. (Subject explained that this is not a task that he has performed in the past with an MFD nor would he attempt to do so with the EX5000c).
6. Estimate Distance- Sectional Score: 1

Flight Plan C

Subject: 8

Instructions: Using the Attached modified-Cooper Harper Scale, please score the following tasks. Space is available for comments as well.

1. Identify controlled airspace restrictions. -- MFD Score: 5
   Hard to tell where to look for labels on Flight Plan B. No labels for Class C? on Flight Plan B.
2. Identify controlled airspace restrictions. -- Sectional Score: 1
3. Locate available navigation aids and/or their frequencies- MFD Score: 4
   Have to capture identifier then go to nearest for freq.
4. Locate available navigation aids and/or their frequencies -- Sect. Score: 1
5. Estimate course- MFD Score: 3
   Course of flight plan scores 1 but that isn’t the question asked. Estimating course not on plan.
6. Estimate Course- Sectional Score: 2

Subjective Questionnaire

Subject: 8

Part I: MFD User Interface
Administer once after completion of flight Plans B and C.
1. What are the best features of the MFD user interface?
   - Excellent display symbology
   - Everything (or most everything) on one page

2. What are the worst features of the MFD user interface?
   - Need to be able to highlight a feature and get info on it without switching pages.
   - Clutter (hard to pick out obstacles)
   - Hard to tell ceilings/floors of Class C/D- would like ceilings/floor for R/MOA airspace

3. What specific things would you like to see different?
   - Declutter settings not very intuitive

Flight Plan D

Subject: 8

Instructions: Using the Attached modified-Cooper Harper Scale, please score the following tasks. Space is available for comments as well.

1. Ability of user to read and interpret available information. – MFD

   Score: 3

   Low obstacles add way too much clutter. Had to turn them off to be able to read MFD. Low Obstacles on Scores 7.

2. Assessing time/distance from the aircraft to map specified objects. – MFD

   Score: 4

   Have to use Kentucky Windage

3. Identifying potential hazards to flight, e.g. obstacles, airspace, etc. – MFD

   Score: 2

   Low Obstacles Off 2

4. Finding useful information at approach, destination, or along flight path. – MFD

   Score: 4

   More desirable to highlight feature and display info without switching pages.
Flight Plan E

Subject: 8

Instructions: Using the Attached modified-Cooper Harper Scale, please score the following tasks. Space is available for comments as well.

1. Ability of user to read and interpret available information. – Sectional
   Score: 1

2. Assessing time/distance from the aircraft to map specified objects. – Sectional
   Score: 2

3. Identifying potential hazards to flight, e.g. obstacles, airspace, etc. – Sectional
   Score: 2

4. Finding useful information at approach, destination, or along flight path. – Sectional
   Score: 1

Subjective Questionnaire

Part II: MFD Map and Information Content

Administer once after completion of Flight Plans D and E

1. What do you like the most about the manner information is displayed and the available content?

2. What do you like the least about the manner information is displayed and the available content?

3. What would you like to see different about the manner information is displayed and the available content?

4. Additional Comments on any issue not already addressed can be written here. Thanks for your time and consideration.
   - Easier with more experience.
- SEATAC airport info page runway numbers 16R and 16L overlap each other. Hard to read.
- KPAE airport info runway numbers overlap runway diagram. Hard to read.
- Color legend is not displayed anywhere on screen. Consider displaying a legend in one of SETUP pages or have a way of highlighting a feature (MOA for example) to understand what it is and pop up a description.
- No altitude label displayed for Class C when settings shoe ON Label ✓
- Bug in KJAX Class C label. Outer label 40/SFC same as inner label 40/SFC. Should be 40/12.
- Some ceiling/floor labels on/ some labels off for Class C. Should all be on or off.
Sources

The following list also includes sources that were not directly cited in the body of the thesis but were invaluable to me as background information and critical to my understanding general aviation, aviation human factors, and basic design.


Crawley, Ed. Lectures during graduate course titled System Architecture at the Massachusetts Institute of Technology. Fall Semester 2000.


MacClellan, J. Mac. “Avidyne Pulls It All Together.” *Flying.*

<http://flyingmag.com/Avionics/ArticleDisplay.asp?ArticleID=42>


