Utility and Recognition of Lines and Linear Patterns on Electronic Displays Depicting Aeronautical Charting Information

Divya C. Chandra

UTILITY AND RECOGNITION OF LINES AND LINEAR PATTERNS ON ELECTRONIC DISPLAYS DEPICTING AERONAUTICAL CHARTING INFORMATION

Divya C. Chandra
United States Department of Transportation
John A. Volpe National Transportation Systems Center
Cambridge, MA

A study was conducted to explore the utility and recognition of lines and linear patterns on electronic displays depicting aeronautical charting information, such as electronic charts and moving map displays. The goal of this research is to support the development of more standardized and consistent lines and linear patterns for these displays. Data were collected from 273 professional and private pilots. First pilots sorted the names of 65 types of lines and linear patterns in terms of utility of the item. Next they tried to identify nine test linear patterns shown in isolation. Results of the sorting task indicated that the most broadly useful items are controlled and special use airspace. Pilots had difficulty identifying the test patterns, but some patterns were better recognized than others. Results for both tasks varied based on pilot background, such as whether the pilots were qualified for instrument operations or visual operations only.

Current standards and recommendations for electronic aeronautical symbols are documented in the 1997 Aerospace Recommended Practice (ARP) 5289 issued by the Aeronautical Charting Committee within the SAE International Aerospace Behavioral Engineering Technology Committee (SAE G-10). This document contains recommendations for symbols that are primarily shown on charts used during operations under Instrument Flight Rules (IFR), such as instrument approach plates, arrival and departure terminal charts, and enroute charts, although some of the symbols are also found on charts for use under Visual Flight Rules (VFR). Line styles are also recommended in ARP 5289 (e.g., for the missed approach track and airspace boundaries), and there are some general suggestions on using lines of different weights (heavy, medium, and light).

The authors of ARP 5289 (SAE, 1997) expected the recommended symbols to be recognizable by qualified pilots. They also expected that the symbols were simple shapes that could be drawn on the current display technology. Unfortunately, Yeh and Chandra (2005) found that pilots did not recognize some of the recommended symbols. In interviews with manufacturers of electronic moving map displays, it became clear that some of the proposed symbols were difficult to draw on existing displays, so manufacturers were developing their own symbols. Another possible explanation for the lack of standardization in current displays is that manufacturers were not aware of the guidance in ARP 5289 because it was not invoked by a regulatory authority such as the Federal Aviation Administration (FAA). In any case, some of the recommended symbols in ARP 5289 are not in widespread use.

In order to support the development of more standardized symbols, lines, and linear patterns for electronic aeronautical displays, the SAE G-10 Aeronautical Charting Committee is updating ARP 5289; the reissued document will be ARP 5289A. The John A. Volpe National Transportation Systems Center (Volpe Center) is working with this industry committee with funding and support from the FAA. Past research conducted by the Volpe Center in support of recommendations for electronic symbology is documented in various reports and papers (Yeh and Chandra, 2005; Yeh and Chandra, 2006; Chandra and Yeh, 2007; Chandra, Yeh, and Donovan, 2007). The earlier studies focus on pilot recognition and identification of navigation aids, while the later studies also address other symbols (e.g., obstructions and markers) and explore broader issues (e.g., line style conventions and classification of symbols into groups).

The Volpe Center's latest task is to provide objective data upon which to base decisions about what lines and linear patterns should have specific recommendations in SAE ARP 5289A and what those recommendations should be. Therefore the purpose of this study is to understand what lines and linear patterns are most useful to pilots, and to understand which, if any, linear patterns are currently well recognized. A more comprehensive technical report on this study is in Chandra (2009).

Previous studies did not address lines on electronic charts and map displays in detail. Chandra and Yeh (2007) did include a short exploration of line styles, in which pilot knowledge of line style conventions for paper charts and electronic map displays was assessed. The results showed that pilots are fairly knowledgeable about line conventions on paper charts, but that line conventions on electronic displays are not as well known or established. Lines and linear patterns currently in use by several manufacturers are documented in Yeh and Chandra (2008). This

study and ARP 5289A address both lines *and* linear patterns, which are similar, but distinct, elements. In ARP 5289A, the term *line* refers to an element typically used to denote a boundary. Lines vary from one another in terms of width (e.g., thick or thin) and/or style (e.g., dotted, dashed, bold). A *linear pattern* may also be used to denote a boundary, but it is represented by a set of repeated patterns or symbols (e.g., several x's along a row).

Method

The study was conducted via paper questionnaire and consisted of two main tasks:

1) Line Sorting. Which lines and linear patterns are most useful?
2) Linear Pattern Recognition. Are there some linear patterns that are well recognized?

The Line Sorting task is designed to address the SAE Aeronautical Charting Committee's goal of identifying which lines and linear patterns should be associated with specific recommendations. The Linear Pattern Recognition task addresses the SAE Aeronautical Charting Committee's goal to understand what current linear patterns are well recognized. Pilots also responded to a set of subjective questions about lines and linear patterns, but those results are not discussed here; see Chandra (2009) for a discussion of the subjective pilot input.

Participant Recruitment and Background Information

Pilots were recruited from United States (US) domestic airlines, international airlines, the Air Force Flight Standards Agency, corporate operators, and private pilot organizations. Some US Government employees from the FAA's Flight Standards Service also participated. International respondents to the questionnaire were based in Australia, Canada, Denmark, England, Germany, Lebanon, Netherlands, New Zealand, and Mexico. Pilots were not compensated for their participation.

The questionnaire was initially sent to 242 instrument-rated pilots. A few months later, it was sent to 355 pilots qualified for visual operations. Pilots were allowed three to four weeks to complete and return the material. Overall, 273 questionnaires were returned with signed informed consent forms, yielding a 46% response rate.

Background information was gathered about pilot ratings and certificates, flight experience, avionics experience, and chart experience. There were 130 pilots in the Instrument Flight Regulations (IFR) Pilot group, which included pilots who reported either Instrument Ratings or Air Transport Pilot ratings. The IFR Pilots included all air transport, corporate, and international operators. The IFR Pilot group also included pilots who conducted military operations, private IFR operations, and even pilots who had experience with operations under Visual Flight Regulations (VFR), but were qualified for IFR operations. The VFR Pilot group had 143 pilots, and included pilots who reported that they held only a private pilot (VFR only) rating. Some of the VFR Pilots had instrument experience but were no longer current in instrument operations.

VFR Pilots reported lower total flight hours; IFR Pilots had a median experience of 9775 flight hours while the VFR Pilots had a median of 377.5 flight hours. The VFR Pilot group also included a higher percentage of pilots 61 and older (34% of VFR Pilots were 61 or older, while just 12% of IFR Pilots were 61 or older). Most pilots reported a typical flight length between one to three hours, with VFR Pilots flying more flights under one hour, and more IFR Pilots with flights longer than three hours. Most VFR Pilots (83%) reported that they only used NACO charts. Some IFR Pilots (39%) used Jeppesen charts exclusively, but many also had extensive experience with other charts, including NACO charts and charts from other sources (e.g. Lido, and charts produced by various governments). Of the pilots flying air transport operations, 80% reported Jeppesen chart experience.

Procedure

There were two sections in the first distribution of the study sent to instrument rated pilots. The first addressed line styles and the second addressed an unrelated research topic; both sections together took approximately 45 to 60 minutes to complete. The second distribution of the study, sent to non-instrument rated pilots, did not include the unrelated task reducing the total experiment time by approximately 15 minutes.

Using the instructions shown below in Figure 1, participants first sorted 65 types of line and linear patterns according to their usefulness. The names of the 65 items were printed on label sheets, one item on each label, in alphabetical order. No images of the items were shown in this task. (For a list of all the items, see Chandra, 2009.) Participants placed the labels for the two most useful categories onto separate sheets of paper, one that was titled

"Items that I find to be very useful in general" and the other that was titled "Items that I recognize and use on occasion." Items that the participant did not commonly use, or did not recognize were left on the label sheets.

(a) *Items that I find to be **very useful in general**.* These are items that you know well and refer to frequently. They should be easily identifiable. Place these items on the first sheet of paper.

(b) *Items that I **recognize and use on occasion**.* These are items that you use on occasion, but not as frequently as those you would place on the other sheet of paper. Place these items on the second sheet of paper.

(c) *Items that I **do not commonly use, or I do not recognize**.* These are items that you seldom use, or you are not sure of their meaning and need more information in order to understand their use. Leave these items on their original label sheet.

Figure 1. Instructions for Line Sorting task

In the Linear Pattern Recognition task, pilots saw nine test linear patterns, which they were asked to identify and indicate their confidence in the response. If they did not know what the linear pattern represented, they were instructed to place a "?" in the response field. A sample question is shown in Figure 2. The linear patterns were selected for this task by subject matter experts on the SAE G-10 Aeronautical Charting Committee. The patterns included two options for the Air Defense Identification Zone (ADIZ) (one that was used by both Jeppesen and Lido, and the other recommended by the ICAO), and one option each for the Air Route Traffic Control Center (ARTCC), Communications, Controlled Airspace, Flight Information Region (FIR), International, Special Use Airspace (SUA), and Time Zone boundaries. In addition, one fake pattern was used as a baseline for comparison.

Line pattern (or ?): _____

1 2 3 4 5 6 7

Low Confidence **Medium Confidence** **High Confidence**

Figure 2. Sample linear pattern question.

Analyses and Results

To understand which items were considered Very Useful overall, responses to the Line Sorting task were tallied within pilot groups (IFR and VFR). A Chi-square test was performed to determine which airspaces and boundaries received a statistically significant number of responses in each response category for each pilot group. The test determined whether the number of responses in the category was statistically different from chance, which would have produced evenly distributed responses (i.e., 1/3 in each of the three response categories).

Results for the Line Sorting task are summarized in Table 1, which lists only the 26 lines and linear patterns that were considered Very Useful by the IFR and/or VFR Pilot groups based on the statistical test. While some items are important to both groups (e.g., controlled airspace) some are understandably Very Useful to only one or the other group (e.g., missed approach procedure tracks for IFR pilots and city patterns for VFR Pilots). For more information about the meaning and use of the individual items, consult Chandra (2009), the Federal Aviation Regulations/Aeronautical Information Manual (FAA, 2007), and/or the FAA Instrument Procedures Handbook (FAA, 2007).

Responses to the Linear Pattern Recognition task varied because of the free-response nature of the task; pilots sometimes used different words to express similar concepts. In order to understand the results, the responses were coded into categories. The categories were constructed with the aid of the SAE G-10 Aeronautical Charting Committee, which reviewed a partial set of data (the first 50 responses) to help the Volpe Center to determine which responses were correct and which were not if there was any question about the response. For example, the Committee determined that "Air Traffic Control *Sector* Boundary" was an incorrect response to the linear pattern that showed an Air Traffic Control *Center* Boundary," because a *Sector* is just one part of the *Center.* In addition,

when determining overall accuracy, "Can't Tell" responses (indicated with a question mark in the response) were considered incorrect because the pilot admitted to not recognizing the pattern, whereas Missing responses were excluded from the analysis because the pilot may have left the response blank for other reasons. Final results of the analysis indicate how accurately the symbols were recognized. A similar process for handling responses is described in Chandra and Yeh (2007) in more detail.

Table 1. *Items considered Very Useful by IFR Pilots and VFR Pilots.*

Item	IFR Pilots	VFR Pilots
Air Defense Identification Zones (ADIZ)	x	x
Class B Airspace	x	x
Class C Airspace	x	x
Class D Airspace	x	x
Prohibited Airspace Area (P)	x	x
Restricted Airspace Area (R)	x	x
Enroute ATC Holding Pattern	x	
Missed Approach Procedure Holding Pattern	x	
Missed Approach Procedure Track	x	
Terminal ATC Holding Pattern	x	
Terminal Procedure Flight Track	x	
Terminal Transition or Feeder Route (Arrival, Departure, Approach)	x	
Enroute Airway or ATS Route	x	
Terminal Control Area (TCA/TMA)	x	
Warning Area (W)	x	
Telephone or Power Lines		x
City Pattern		x
Class E Airspace		x
Contours		x
Lake or Pond		x
Military Operations Area (MOA)		x
Railroad (single or multiple track)		x
River or Stream		x
Road (single or multi-lane)		x
Shoreline		x
Temporary Flight Restriction Area (TFR)		x

Results for the Linear Pattern Recognition task are summarized in Table 2, which shows the percentages of Can't Tell and Missing responses, as well as responses accuracies for the IFR and VFR Pilot groups for each of the nine test patterns. Preliminary testing of the linear patterns had indicated that the identification task would be difficult without context (e.g., cues about the linear pattern's shape, size, and relative location on the display), and the final data confirmed this expectation. Notice that the fake pattern was actually the most difficult pattern for the participants to identify as expected. The IFR and VFR Pilot groups differed in their response accuracies to six of the nine linear patterns; statistical significances for the differences are shown in the rightmost column of Table 2.

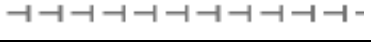
Discussion

Results of the Line Sorting task identified lines and linear patterns that were very useful to IFR and VFR Pilots. Chandra (2009) provides a more detailed breakdown of these results based on the pilot background. These results may be used by the SAE G-10 Aeronautical Charting Committee to determine which lines and linear patterns should be assigned specific recommendations in ARP 5289A. For example, recommendations may be most useful for the items considered Very Useful by *both* IFR and VFR Pilots listed in Table 1, such as the different Airspace Classes, and Prohibited/Restricted Areas. Regulatory authorities can then use either the full results of this study, or the ARP5289A document to determine if the information needs of the pilots are met by a given display.

The full results of the Line Sorting task presented in Chandra (2009) can also be used by manufacturers to determine what lines and linear patterns would be useful to pilots given a particular type of flight operation. For example, Chandra (2009) provides a breakdown of results for flight operation type. Manufacturers of displays for

private pilots, as an example, may want to review Chandra (2009) to understand the results across all their potential customers including Private VFR, Private IFR, and Private Business operators.

Table 2. *Summary of results for the Linear Pattern Recognition Task.*

Test Item	Linear Pattern	Can't Tell Responses Overall	Missing Responses Overall	IFR Pilot Accuracy (N=130)	VFR Pilot Accuracy (N=143)	IFR vs. VFR Pilots Statistical Significance
ADIZ Option 1 (ICAO)		36%	22%	22%	49%	$F(1, 210) = 18.7$, $p < 0.001$
ADIZ Option 2 (Jeppesen/Lido)		68%	11%	28%	4%	F(1, 241) = 30.1, p < 0.001
ARTCC		58%	11%	20%	16%	No significant difference
Communications		60%	10%	34%	0%	F(1, 243) = 67.3, p < 0.001
Controlled Airspace		24%	26%	37%	49%	No significant difference
Fake Pattern		70%	13%	n/a	n/a	n/a
FIR		44%	26%	47%	7%	F(1, 199) = 47.4, p < 0.001
International Boundary		32%	25%	35%	50%	F(1, 204) = 5.16, p < 0.05
SUA Boundary		22%	11%	54%	48%	No significant difference
Time Zone		37%	26%	45%	14%	F(1, 200) = 26.2, p < 0.001

Results of the Linear Patterns Recognition task may be used in identifying whether some linear patterns are currently well recognized, and should be recommended for use as is. Recognizing linear patterns in isolation was a difficult task and overall recognition rates were relatively low, particularly in comparison to the recognition rates obtained for identifying specific symbols such as the navigation aid symbols and other general symbols that were evaluated in Chandra and Yeh (2007). The most recognizable linear pattern was the Special Use Airspace Boundary, which obtained a 51% recognition rate overall, whereas navigation aid symbols were typically recognized by pilots 80% of the time or better. Although the recognition rates for linear patterns were relatively low overall, some patterns were better recognized than others and these results may be used by the SAE G-10 Aeronautical Charting Committee to determine which linear patterns should be included in ARP5289A. Even if the linear pattern is not recognized by a majority of pilots, reusing an existing symbol will aid pilots who are familiar with it, and it may reduce future potential conflicts with that symbol.

Summary and Conclusions

This report provides an overview of a study conducted to explore the utility and recognition of lines and linear patterns on electronic displays depicting aeronautical charting information, such as electronic charts and moving map displays. Further details about this study are reported in Chandra (2009).

The results of this study provide valuable information for the development of an industry recommendations document that will help manufacturers and regulatory authorities assess whether the information needs of the pilots are met by various electronic displays of aeronautical charting information. In order to maximize the applicability of the results, data were collected from pilots who fly all types of operations, from around the world. Items that were useful to different pilot groups were identified based on pilot qualifications, types of flight operations, and typical flight length. Recognition of a test set of nine linear patterns was difficult, but some patterns were more recognizable than others.

Results of this study will be considered in the development of an updated industry recommendations document, specifically, the SAE International Aerospace Recommended Practices (ARP) document on Electronic Aeronautical Symbols (ARP 5289A). The FAA, other civil aviation authorities, or ICAO the may choose to adopt

this industry document by reference at a later date. Note that this research applies to any electronic display that shows the lines and linear patterns tested in this study, regardless of the intended function of the display, so its applicability may be far reaching.

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