# PILOT INFORMATION NEEDS FOR ELECTRONIC DATA-DRIVEN CHARTS

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Electronic charting technology is evolving from "fixed" raster-based charts to data-driven charts, in which information elements shown on the chart can be re-configured during flight. Specifically, we were interested in indentifying a set of minimum information requirements for a concept in which pilots brief with a fixed chart showing *all* information elements but then fly with an electronic chart, which may or may not include all the information elements that were briefed. Two hundred twenty-nine pilots rated the importance of information elements shown on four different types of aeronautical charts. We analyzed the data using one-way chi-square tests to identify a criticality "level" for each information element. This information was then used to identify a "minimum set." This paper presents an overview of the findings.

Aeronautical charting has evolved with changes in display technology, expanded use of global position systems (GPS), and increased processing capabilities. With each evolution, the usability of the aeronautical chart needs to be considered. For example, early research in the design of aeronautical charts focused on the usability of paper Instrument Approach Procedure (IAP) charts, which provide a visual representation of the information pilots need to fly an approach. Pilots indicated that these charts were cluttered - yet sometimes excluded needed information, and were difficult to read to the extent that pilots could not find information (Cox and Connor, 1987; Ashworth, McBain, Bassett, Moran, Soderlind & Buck, 1975). Additionally, the presentation of information (e.g., the layout, font, symbology) differed across chart providers. To address these concerns, the Volpe Center conducted a series of studies in the 1990s to improve information search on IAP charts. The results of this research led to the introduction of the "briefing strip" format which had the following properties:

- A briefing strip at the top of the chart to promote briefing as a critical component of flying an approach, and to present the required information in a logical order in one place.
- A boxed layout for heading and frequency information (see Multer et al., 1991).
- Graphical icons to depict missed approach information (see Osborne & Huntley, 1992).

As aeronautical chart information moved from paper to electronic mediums, research examined how to organize and "layer" information elements, so that the information could be added or removed. Pilot surveys were conducted to identify critical information elements for instrument approach charts (Hansman and Mykityshyn, 1995a) and surface moving maps (Yeh and Chandra, 2005). Additionally, Schvaneveldt, Beringer and Lamonica (2001) conducted a survey to identify critical information elements for flying in general. Collectively, the results showed that "critical" information elements differed depending on the phase of flight. Hansman

and Mykityshyn reported that pilots were interested in the ability to declutter information but were concerned about the ability to retrieve the suppressed information when needed.

As electronic charts become integrated into flight decks, the design of the chart may diverge further depending on the manufacturer's design philosophy. The simplest electronic chart is a raster image that is an electronic version of a paper chart. A symbol identifying own-aircraft position may be added if the raster chart is geo-referenced. More complex are vector- and data-driven charts, which provide more capabilites to the end user than raster charts by encoding information about each information element, so that the chart can be re-rendered and re-scaled when the pilot zooms in (or out), allowing the size of the symbols and text to resize in a corresponding way. Users can also add or remove layers of information or select symbols to see more information about that symbol. Thus, the information on the electronic chart can become more specific to the task at hand, the pilot can use manual or automatic decluttering to customize the information, and the chart can be integrated with other map information.

The Federal Aviation Administration (FAA) was interested in understanding whether a minimum set of information elements could be defined for these customizable electronic charts. A couple of attempts have been made so far to characterize the information requirements. For example, SAE ARP 5621 provides a categorization of information elements based on subject matter expert opinion for electronic charts intended to be used as a replacement for paper charts. The SAE Committee decomposed nine chart types into the information elements shown on the charts and evaluated the criticality of each information element for presentation on a fixed chart for briefing or a moving map format for flying the procedure. Each information element was rated as a criticality based on the following:

- Level 1: information elements that can not be removed
- Level 2: information elements that should be shown initially but could be removed by pilot action
- Level 3: information elements that do not need to be presented initially and can be manually selected (or deselected)

Due to the number of information elements, we refer the reader to SAE ARP 5621 for the full classification. These levels, based on subject matter expert opinion, provide an initial framework for organizing information elements.

Pepitone, et al. (2014) provided data for a preliminary validation when they examined the criticality of information elements for integrating instrument flight rules (IFR) procedural chart information onto a forward flight deck display (e.g., a primary flight display (PFD) or multi-function display (MFD)). Twenty Honeywell pilots participated in a card-sorting task in which they rated the criticality of the information elements for flying a procedure using three levels, similar to the ones identified in SAE ARP 5621. The results provided some validation of the SAE framework, but the study was limited in that the data reflected the opinions of corporate pilots only and no statistical analyses were reported.

We wanted to further examine the criticality ratings provided in SAE ARP 5621 and Pepitone et al. Our focus was to identify a set of minimum information elements for a display concept in which pilots brief with a fixed chart that shows *all* information but then fly with a

configurable electronic chart, which may or may not include all the information briefed. Our study addressed four different chart types (IAP, Instrument Flight Rules (IFR) Enroute, Standard Terminal Arrival Routes (STARs), and Standard Instrument Departures (SIDs)).

## Method

### Participants

Participants were recruited in two ways. First, 600 pilots, randomly selected from the Civil Aerospace Medical Institute (CAMI) Aeromedical Pilot Database, were invited to participate in the survey via email. Additionally, 600 invitations were sent via US postal mail to those pilots. To participate in the survey, pilots needed to have flown IFR in the previous 6 months and be a user of FAA, Jeppesen, or U.S. Government (military) charts. These pilots were characterized by pilot type (air transport, corporate, military, general aviation) based on information fields on pilot licenses recorded in the database. Due to a low response rate from the first sample, a second random sample of 600 pilots was selected and invitations were sent for participation. In this first effort, 258 pilots responded (a 21.5% response rate), but only 186 met the criteria for inclusion.

The participants recruited from the Aeromedical Pilot Database were primarily air transport and corporate pilots, so we conducted a second recruiting effort with local universities, military bases, and flying clubs to recruit general aviation and military pilots. We sent emails to 151 pilots, of which, 43 met the criteria for inclusion (28%).

In total 1,351 pilots were invited to participate; 326 responded (a 24% response rate). Of these, only 267 met the inclusion criteria. 229 pilots completed the survey.

### Surveys

The purpose of this research was to gather pilot opinions of the importance of information elements shown on four types of charts: IAP, IFR, STARs, and SIDs. Due to the number of information elements on each chart, we created two surveys: one that included information elements on IAP/IFR charts (221 information elements), and the other with information elements from SID/STAR charts (206 information elements). Participants were randomly assigned to a survey. 114 pilots responded to the IAP/IFR survey, and 115 to the SID/STAR survey. The number of participants by pilot type are shown in the table below.

Table1. *Distribution of Participants by Pilot Type*

| Pilot Type | IAP/IFR Participants | SID/STAR Participants |
|---|---|---|
| Air Transport | 30 | 30 |
| Commercial | 30 | 30 |
| General Aviation | 30 | 30 |
| Military | 24 | 25 |

The median time to complete the IAP/IFR survey was 38.5 minutes; the median time to complete the SIDs/STARs was 28.9 minutes.

Participants completed a background questionnaire first before being presented with the information element survey. In the survey, participants were instructed to rate the importance of aeronautical information elements for a new charting concept using customizable electronic charts that are interactive and customized to display only information elements needed to execute the procedure. In particular, we emphasized that the customizable electronic chart would show only the information relevant to the procedure being flown. Category definitions were modified from the SAE ARP 5621 for the specific intended function. Pilots were asked to rate each information element individually with respect to aircraft operation when executing the procedure and not on the frequency of use. Ratings were made along four levels of importance. A fifth level was included if participants did not know the information element.

- 1 = Required to be displayed continuously for the safe and successful execution of the instrument flight procedure.
- 2 = Displayed initially, but can be removed and recalled for reference, as needed.
- 3 = Not displayed initially, but can be displayed manually for reference, as needed.
- 4 = Not required to execute the procedure.
- Don't know/Unsure

Pilots were presented with charts that depicted as many of the information elements being rated as possible. A sample is shown in Figure 1.

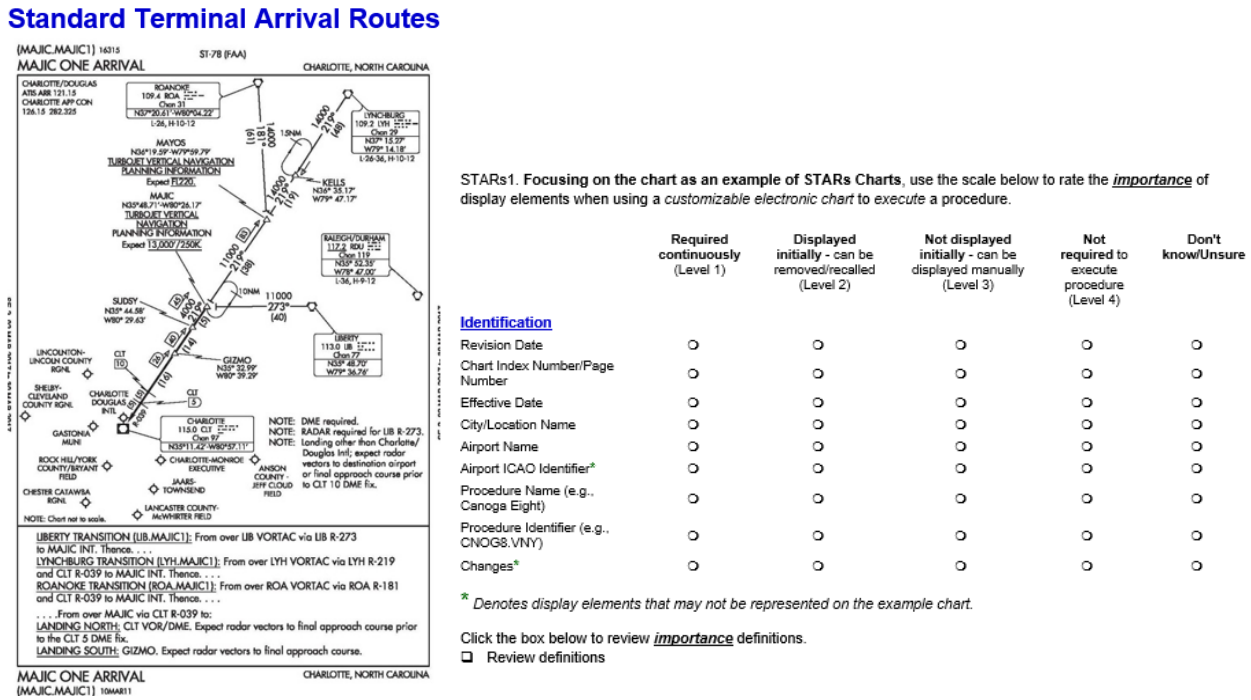


*Figure 1.* Example of STAR survey with response options.

Approximately 32% of the information elements on the IAP/IFR survey and 53% of the information elements on the STAR/SID survey were not depicted. An asterisk denoted this.

## Results

The frequency of responses for each level for each information element were calculated and analyzed using a series of chi-square tests. We developed the following framework with which to analyze the data:

1. Did pilots feel that the information element was required to be displayed to successfully execute the procedure? (Levels 1, 2, and 3 vs. Level 4)
2. If yes to 1, did pilots feel that the information element was required to be displayed at all times to successfully execute the procedure? (Level 1 vs Level 2, or Level 1 vs Level 3)
3. If the information element was not required at all times (Levels 2 and 3), did pilots feel that the information element should be displayed initially (Level 2 vs. 3)?

We compared the results of our analysis to the subject matter expert assessments captured in SAE ARP 5621 and the data provided by Pepitone, et al. (2014) as an intial validation. A subset of the critical (Level 1) information elements for each chart (post-comparison) are shown in Table 2 below. **This is not a complete list.** For a full list, the reader is referred to the technical report (in preparation).

*Table 2.* Sample of Level 1 (highest criticality) elements by chart type.

| **IAP** | **IFR** |
|---|---|
| Airport Elevation | Airway Designator |
| Airport Identifier | Airway Magnetic Course |
| All appropriate Navaid Symbols | Airway Symbol (center line) |
| Communications Tower Frequency | Area Minimum Altitudes – OROCA Sector Altitudes |
| FAF (Maltese Cross) | Indication of compulsory reporting |
| FAF Crossing Altitude (MSL) (HAT) | Intersection, Waypoint, or Fix Name |
| Fix Altitude | Intersection, Waypoint, or Fix Symbol |
| Fix Information | Minimul Crossing Altitude (MCA) |
| Fix Name/Identifier | Navaid Frequency |
| Fix Symbol | Navaid Identifier |
| GS Intercept Altitude (MSL) | Navaid Name |
| Holding Pattern – Holding Pattern Depiction | Navaid Symbol |
| Landing Minimums CAT 1 Decision Altitude (DA) | Segment Minimun Cruising Level or MEA |
| Landing Minimums – Minimum Descent Altitude (MDA) | Indication of MET Report Required |
| Landing Runway Number | Air Defense Identification Zones (ADIZ) |
| … | … |
| **SID** | **STAR** |
| Airport Elevation | Airport Identifier |
| Airport Identifier | Airport Name |
| Airport Name | Course Definition – Heading |
| Course Definition – Heading | Course Definition – Radial |
| Course Definition – Radial | Course Definition – Segment Mileages |
| Course Definition – Track | Course Definition – Track |
| Instrument Procedure Course/Tracks – Identifier | Holding Pattern Depiction |
| Instrument Procedure Course/Tracks – Symbol | Instrument Procedure Courses/Tracks – Identifier |
| Intersection /Fixes on Procedures – Identifier | Instrument Procedure Courses/Tracks – Symbol |
| Navaids for Fixes – Identifier | Intersection/Fixes on Procedures Identifier |
| Navaids for Fixes – Symbol | Navaids for Fixes – Symbol |
| Navaids for Legs – Symbol | Primary Airport Elevation |
| Procedure Name | Primary Airport Runway Layout |
| Transition Course Depiction | Procedure Name |
| Transition Name | Textual Information Crossing Altitude Restrictions |
| … | … |

## Conclusions

This study presents a first step in identifying critical information elements for configurable electronic charts. The results shown here reflect pilot opinions of the importance of each information element for a new charting concept in which pilots brief with a fixed chart and fly with a reconfigurable electronic chart. Our next step is to ensure that the relationships between information elements is reflected appropriately (e.g., that related items that need to be shown at the same time are categorized the same way). Validation, potentially through simulation testing, is also needed to ensure that the prototype charts can be used during flight.

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