DESIGN AND EVALUATIONOF INSTRUMENT APPROACH PROCEDURE CHARTS

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OVERVIEW

A new format for instrument approach procedure charts has been designed. Special attention was paid to improving the readability of communication frequencies, approach course heading, and missed approach instructions. Selected components of the new design were evaluated in the laboratory. Other details, including design trade-offs, were determined from expert opinion. One version of the new chart is intended for use by large air carriers. A field evaluation of this chart is being conducted through the combined efforts of the federal government, a commercial publisher of instrument approach plates, and several major airlines.

CHARACTERISTICS OF IAP CHARTS

Figure 1 shows an instrument approach procedure (IAP) chart published by the U.S. Government National Oceanic Service (NOS). The density of information on the chart is very high, the alphanumerics are very small, and safety critical information is spread throughout the chart. These charts often must be read under difficult circumstances that further degrade their readability. An instrument approach in a cramped, poorly lit and bouncing cockpit is a high workload operation. All chart designers recognize that these characteristics contribute to making the charts difficult to read but have limited flexibility for improving chart design.

There are several reasons for the current design of approach charts. Information density is high because each chart must include the information required for single and multi crew operations, fast and slow aircraft, professional and pleasure pilots, and advanced as well as low technology cockpits. The same standard format must be used for both simple and complex approach procedures so that pilots know where to look for the information that they need. The charts are small because books of charts must be convenient to be carried by the pilot, and easy to handle in small cockpits. They must be relatively inexpensive because they are updated frequently and are purchased in enormous quantities by air carrier companies.

When we have the technology to inexpensively present charted information in the cockpit electronically many of these problems will disappear. Pilots will be able to select only the information that they need for the current approach, color will be used to identify certain classes of information, and windowing will provide high priority information on demand. However, this technology will not be available in many air carriers for some time. Air carrier companies estimate that they will be using paper charts for at least another ten years. Low end general aviation aircraft will be using paper charts for far longer.

PROTOTYPE DEVELOPMENT

The purpose of our initial development work was to improve the readability of U. S. Government approach charts. All of our laboratory work was done with NOS charts. During this work, which continues, we had the opportunity to work with the Air Transportation Association's Charting and Data Display Working Group to develop a second prototype chart. This chart incorporates many of our laboratory findings in a design developed specifically for air carrier operations. It is based upon the format currently used in most major air carriers which is produced by Jeppesen Sanderson, Inc.

The design tools used to create this prototype are among those reviewed and discussed by Mangold, Eldridge, and Lauber (1992). These include increasing white space around high priority information and highlighting through a variety of means such as changes in line width, boxing, and font style; location of information; and grouping of information. In addition, Osborne and Huntley (1992) have shown that use of icons rather than text can increase the speed of information transfer.

Laboratory

Variations in the depiction of communication frequencies and track headings for the final approach course (Multer, Warner, Disario, and Huntley, 1991), and iconic depiction of missed approach instructions (Osborne and Huntley, 1992) were evaluated in the laboratory.

In each case relevant components of NOS charts, or complete charts with the appropriate modifications were presented tachistoscopically to private and airline pilots. Typically the pilot initiated the presentation of the chart on a rear projection screen. The time required for the pilot to verbalize the target information (e.g. a frequency or inbound heading) or the number of "looks" necessary for a pilot to verbalize a missed approach instruction was recorded, as was response accuracy.

Statistically significant differences among treatment conditions were found in each of the three studies. Frequencies depicted in boxes were identified more quickly than when left justified and listed beneath or next to the facility name. Boxed and reverse video depiction of headings were more quickly identified than when headings were unbolded or bolded. (However, pilots reported the reverse contrast to be so prominent as to be distracting.) Pilots required fewer looks to verbalize iconically presented missed approach instructions than when they were described in text. Although pilots stated that they would prefer the text if they had to describe the instructions to another pilot, they would prefer the icons if they had to fly the missed approach in single pilot operations. No statistically significant differences in error rates between text and iconic presentations were found.

Expert Opinion

Prototypes of NOS charts incorporating changes indicated by the laboratory research were reviewed by the several technical committees concerned with charting including the Federal Aviation Administration's Government/Industry Charting Forum and the Society of Automotive Engineers' Subcommittee on Aeronautical Charting. Based on these discussions, a "briefing strip" (Figure 3) incorporating the communications frequencies was created for the top of the NOS chart.

With the exception of the approach light configuration that the pilot should see when he breaks out, this strip colocates nearly all the information that the crew needs to prepare for the approach. The numbers critical to navigating the final approach course are on the top line for quick reference in case of a last minute runway change. The communications frequencies in the second row are in the order in which they will be used. Font size of the frequencies is relatively small because this information is normally used as a backup to information normally provided by air traffic control. The notes and missed approach text are shown in the third line to facilitate quick review prior to initiating the approach.

Additional changes include bolding minimum altitudes in the tables at the bottom of the chart. The MSA circle has also been changed. The primary navaid is identified in the center of the circle. Sectors of the circle are defined by radials rather than bearings to the station to be consistent with the way the National Airspace System is defined. The altitudes in the sectors are represented by the same kind of notation used in VFR sectionals to make them more easily read at a glance.

All of these changes have been incorporated in the prototype version of the NOS format. Initial comments to the format are being solicited by the FAA through a mail survey to Charting Forum members. Additional testing will be conducted with students during instrument flight training. This flight evaluation will compare the time required by pilots to identify information critical for instrument approaches on original and prototype NOS IAP charts.

Volpe/ATA Format

We have been working with ATA to adapt our prototype NOS format to air carrier operations. One advantage of such a specialized application is that it allows the designers to delete information not required for that specific use. The prototype features developed for the NOS format are incorporated in the Volpe/ATA chart shown in Figure 4. This chart is based upon the Jeppesen Sanderson format normally used by air carriers. It incorporates chart modifications evaluated in our laboratory as well as those developed from recommendations by air carrier pilots. Selected information elements have been deleted from the plan view portion of the chart to reduce clutter. The middle marker and the Morse code identifier for the primary navaid were deleted because they repeat information contained in the profile view. Depiction of all obstacles and airports beyond five miles from the approach course were also deleted.

Because the larger air carriers do not fly approaches slower than 120 kts, data for Category A and B approaches were deleted from the tables at the bottom of the chart.

FIELD EVALUATION

The Volpe/ATA chart will be evaluated at the training centers of Continental, Delta, Federal Express, Northwest, and United Airlines. The purpose of this evaluation will be to identify design elements of the prototype charts that air carrier pilots like and design alternatives that they would prefer over both the prototypes and the charts that they currently use.

The field evaluation will also include an assessment of a prototype chart developed by Jeppesen Sanderson, Inc. It is a variation of their standard format that incorporates some of our laboratory findings and modifications requested by the ATA working group. Although the basic shell of the chart is unchanged from their standard publication it's readability appears to be improved by reorganization of the communications frequencies, adoption of our design of the MSA circle, and bolding of selected information.

Approach

Details of the evaluation procedures vary among the airlines, depending upon such factors as personnel and simulator availability, but the basic approach will be the same.

Each of the five airlines will provide ten two-member flight crews, At each airline's flight training simulation facility, five crews will *fly* six approaches with the Volpe/ATA prototype chart and four approaches with the standard Jeppesen Sanderson charts that they currently use. The other five crews will *fly* six approaches with the Jeppesen Sanderson prototype and four approaches with the standard Jeppesen Sanderson charts. Five approaches will be flown to touchdown and the remaining five will conclude with a missed approach procedure. Six different approach procedures (three precision and three non-precision) will be sequenced along with the designation of the pilot flying (PF) and the pilot not flying (PNF) such that the PF does not make the same approach twice. Simulators for both advanced technology and conventional aircraft will be used (e.g., Boeing B-767 and Douglas DC-10, respectively.) An observer will record the crew's comments regarding the chart design and the approach procedures, during the simulator sessions.

Prior to the simulator session, crews will be interviewed regarding their opinions on current approach chart designs. The crews will then be trained in the differences between the standard approach chart and the particular prototype that has been assigned to them. Each crew will fly with only one of the two prototype designs. Crews flying with the Volpe/ATA prototype will also be trained to interpret the missed approach icons.

Following the simulator session, a structured debriefing will be used to obtain the crews' opinions about each design change in the prototype, and recommendations for improvements. Scaling and other techniques to compare the prototypes with one another and the current Jeppesen Sanderson product will be used to elicit and quantify pilot opinion regarding the prototype charts.

The briefings, observations and postflight discussions will be conducted by two-man teams. Each team will include an aviation human factors specialist and a retired airline captain familiar with line operations.

APPLICATION OF RESULTS

This field evaluation will systematically expose air carrier crews to the prototype designs of the approach plates and obtain pilot opinion concerning the new designs. A parallel study will measure how quickly pilots obtain information from the standard and NOS prototype charts. The data from the these two studies and the responses from members of the Government/Industry Charting Forum to the mail survey will be used to develop improved versions of the ATA and NOS prototypes. These updated prototypes will be reviewed and considered by the ATA and Federal Aviation Administration for further evaluation or implementation.

ACKNOWLEDGMENTS

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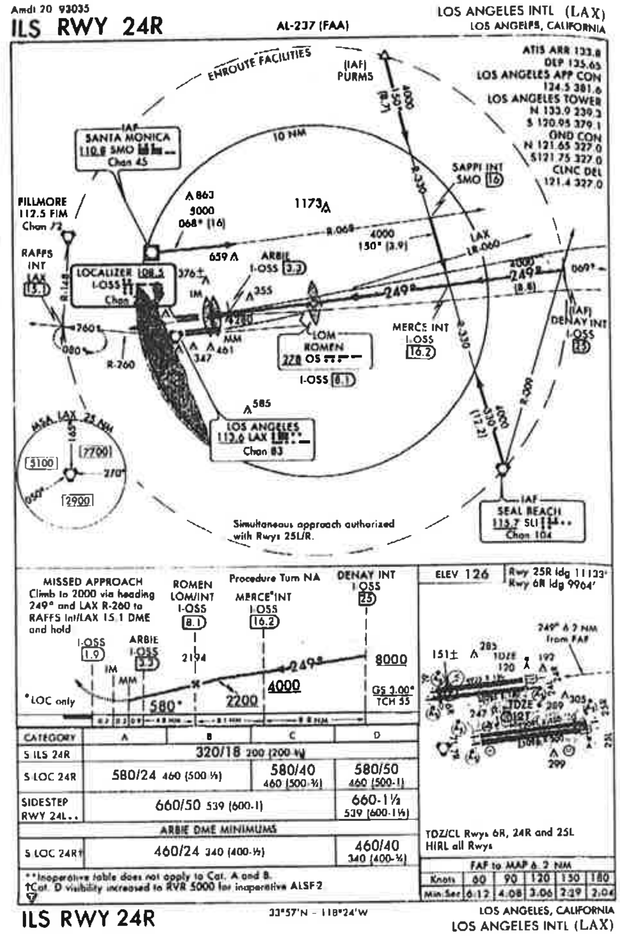

Figure 1. Current NOS chart
(for illustration only, not for navigation)

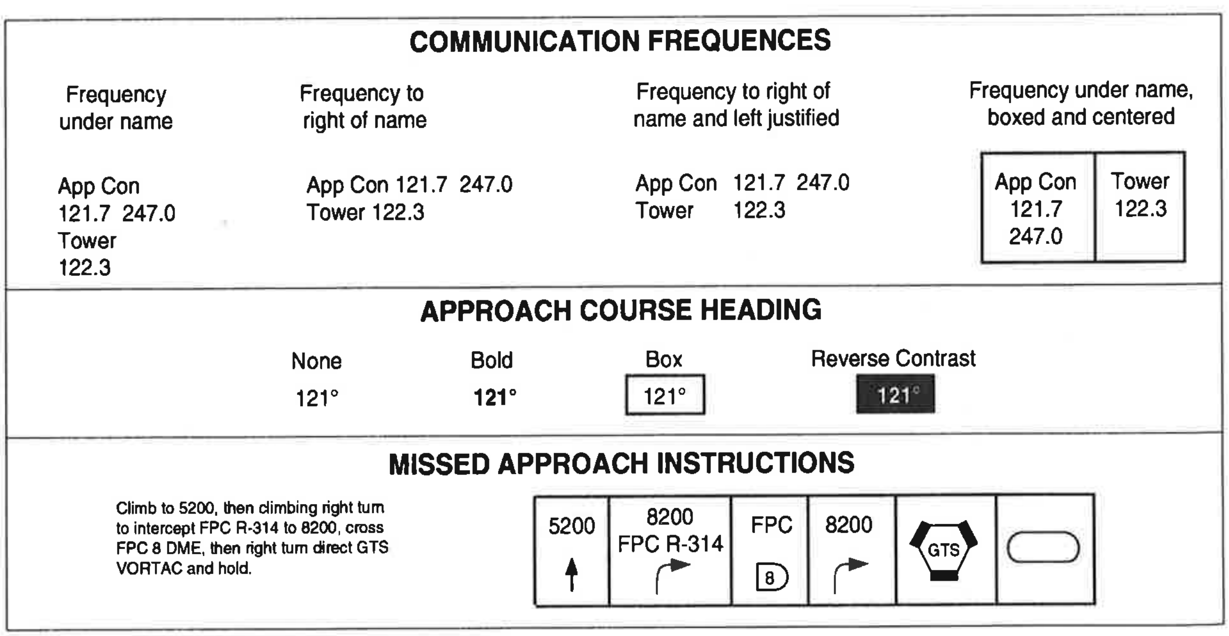

Figure 2. Information formats evaluated in the laboratory

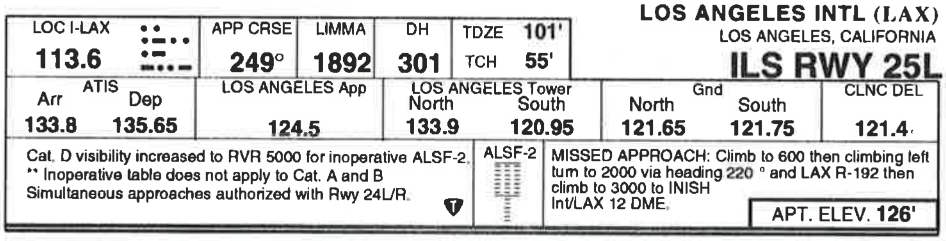

Figure 3. Prototype briefing strip
(for illustration only, not for navigation)

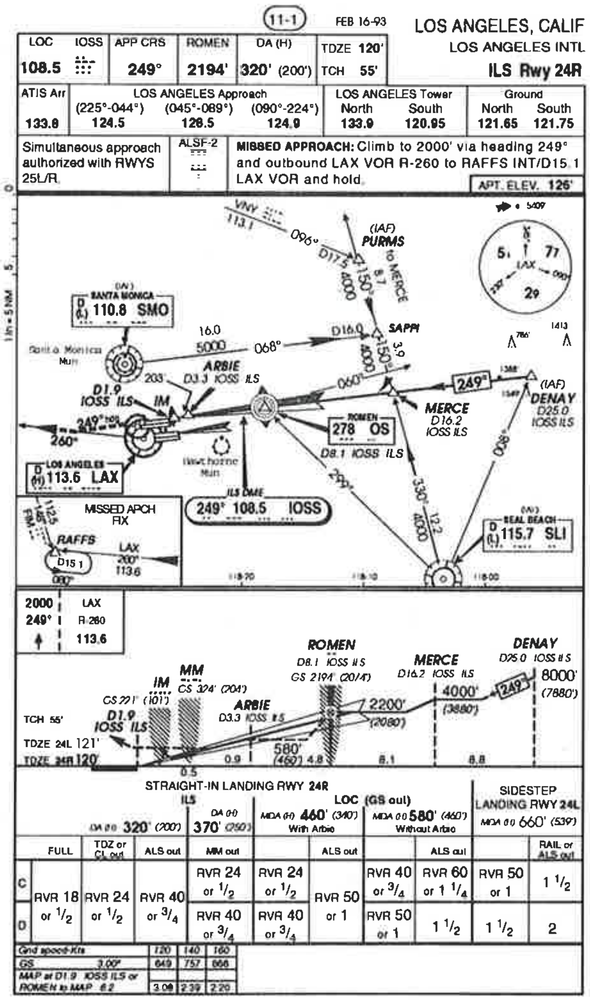

Figure 4. Volpe/ATA format chart
(for illustration only, not for navigation)