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NEW TRENDS IN TECHNOLOGY, AND THEIR APPLICATIONS: DIGITAL DATABASES, GEOGRAPHICAL AND LAND INFORMATION SYSTEMS

The challenges of air traffic control graphics for the Advanced Automation System

Paper submitted by the United States of America**

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INTRODUCTION

In 1981 the Federal Aviation Administration (FAA) developed a comprehensive plan to improve air traffic control (Figure 1) and airway navigation facilities and services. The Advanced Automation System (AAS) is the most complex element and the centerpiece of this $12.2 billion plan. Officials working on the AAS have stated that it will dwarf the Apollo space program in technical complexity (Richardson, 1990). It includes Common Console (CC) workstation equipment for enroute and terminal operations, new workstations for airport towers, and new software and hardware for tower, terminal, and enroute operations.

The first phase of the AAS will be implementation of the Initial Sector Suite System (ISSS), which includes approximately 7500 CC's. The ISSS will provide air traffic controllers with all present capabilities and several new ones in a more responsive and reliable environment, but requires data in a digital format. The Aeronautical Charting Division (ACD) of the National Ocean Service (NOS) presently supplies thousands of paper charts to the FAA and general public. The ACD will convert these charts to digital format and provide them to the FAA on the same 28 day, 56 day and 6 month cycles as the paper charts.

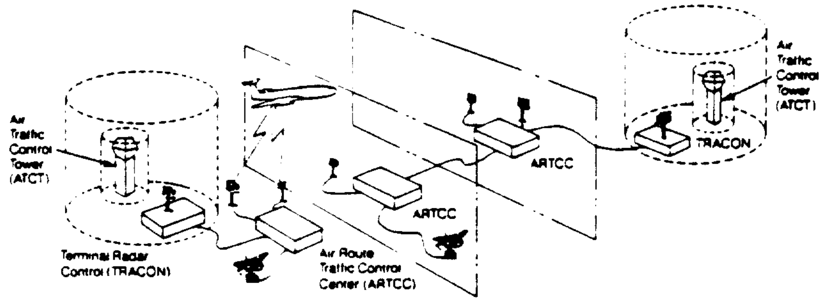
The FAA developed the AAS to improve the safety, capacity, and productivity of aviation services through increased automation (Leyden, 1988). Over 500 million people per year presently use the National Airspace System (NAS), and that figure is projected to increase to over 750 million by the century's end ("The FAA's National Airspace Plan: Meeting the Challenge"). This will place an intolerable strain on the existing air traffic control system.

The FAA awarded International Business Machines (IBM) a $3.6 billion contract to develop the AAS through a new generation of air traffic control hardware and software (McCormick and Messmes, 1988). The FAA has already set the stage for the transition to the AAS by installation of new IBM mainframe computer systems in all 20 domestic enroute control centers (FAA-AP-1990-4906, 1990).

COMMON CONSOLE DESCRIPTION

The CC (Figure 2) is a new workstation for enroute and approach air traffic control. It will replace existing consoles, computer readout displays, flight data input/output devices, and flight strip printouts. The CC's will provide all present capabilities and introduce new functions and capabilities, including the ability to observe and manipulate both radar data (current aircraft position) and flight data (aircraft's intended route to its destination) (FAA-AAP-FIS-5, 1990). About 2,300 Position Consoles (similar to CC's) will be installed at 335 Control

Physical and Functional Elements of Air Traffic Control



Air Traffic Control Tower (ATCT)

- Number - 300
- Functions:
  - —Clearance Delivery
  - —Ground Traffic Control
  - —Active Runway and Airport Traffic Within 5 Mile Radius and <3,000' Altitude

Terminal Radar Control (TRACON)

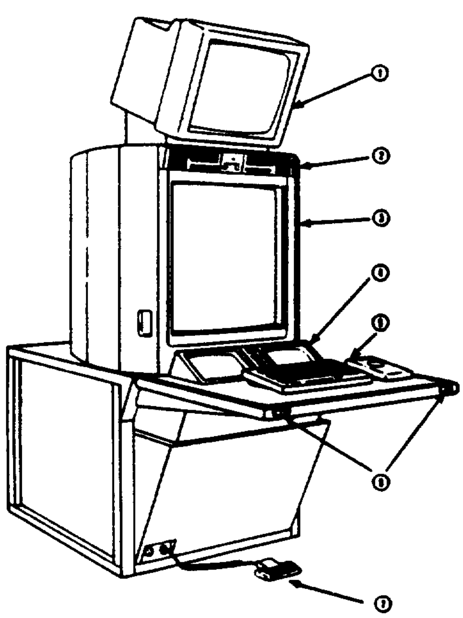
- Number - 186
- Functions:
  - —Radar Separation in Arrival/Departure Flight Phases
  - —Airspace Within 30 Mile Radius and <10,000' Altitude (Exclusive of ATCT Airspace)

Air Route Traffic Control Center (ARTCC)

- Number - 20
- Functions:
  - —IFR Traffic
  - —Radar Separation in Enroute Flight Phase
  - —Procedural Separation Outside Radar Coverage

FIGURE 1

COMMON CONSOLE
Operational Features



1. Auxiliary Display
2. Power and Communications Controls
3. Main Display Monitor
4. Voice Switching and Control System
5. Keyboard and Trackball
6. Headset Jacks (4)
7. Push-to-talk switch

FIGURE 2

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Towers after ISSS implementation.

Two graphic display monitors will be available at each CC:

- Auxiliary Display - a high resolution, multi-color, graphics monitor (10" x 12" landscape format at 100 DPI) used to display maps, charts, manuals, and checklists. The Auxiliary Display will be from 36" to 40" from the air traffic controller, requiring that all data displayed on this monitor be designed for distant viewing.

- Main Display - a high resolution, multi-color, graphics monitor (20" X 20" at 100 DPI) which can display either radar images (including weather) for aircraft tracking or data such as maps, charts, manuals, and checklists.

AAS DATA REQUIREMENTS

The AAS project requires nearly 140 gigabytes of data annually. This includes vector data for Controller Charts, Terminal Procedure Publications (TPP's), and High/Low Planning Charts (57.9 gigabytes) and pixel data for Sectional and U.S. Gulf Coast (Helicopter) Visual Charts (81 gigabytes). The NOS will deliver 0.5 gigabyte of Controller Chart data and 4.2 gigabytes of TPP data in AAS machine compatible vector format each 56 and 28 days respectively (Table 1). Monthly, the NOS will update and revise 1.1 gigabytes of pixel data from the Sectional and U.S. Gulf Coast Charts. This data will be incorporated into the existing 6.8 gigabyte pixel database for these charts and the entire database revised and delivered to the FAA in machine compatible pixel format (Table 2). All data will be reviewed and certified prior to delivery to 20 FAA Air Route Traffic Control Centers (ARTCC's) and the FAA Technical Center, Atlantic City, New Jersey. The data sets will be customized for each ARTCC.

Data delivery schedules will be rigidly enforced--no late deliveries can be tolerated. To ensure the safety of the NAS, digital data must be integrated into the Air Traffic Control System on the issue dates of the paper charts used by pilots and must match exactly the data on the paper charts.

CARTOGRAPHIC CHALLENGES POSED BY THE AAS PROGRAM

The NOS must solve numerous cartographic challenges before providing digital data to the FAA. These challenges are outlined in Table 3 and discussed below:

VECTOR DATA (56 Day Cycle)

Chart Type	Number of Chart Panels	Scale	Total MBytes
SCC*	77 (36" x 36")	1:500K	462
TPP	7400 (5" x 8")	1:500K	4,224
Enroute Planning Chart	(not determined)		unknown

SCC and TPP requirement per 56 day cycle = 4,686
Additional TPP requirement at 28 day update= 4,224

Total SCC and TPP requirement per 56 day cycle = 8,910

Average annual (6.5 cycles) Vector Data requirement = 57.9 Gbytes

* Super Controller Chart--replaces 45 High and Low Controller Charts (40" X 55").

TABLE 1

PIXEL DATA (6 Month Cycle)

Chart Type	Chart Panels (36" X 36")	Scale	MByte Scanned	MByte Revised+
Super Sectional Chart	77*	1:500K	26,862	6,716
U.S. Gulf Coast Chart	1.5**	1:1,000K	234	57

Total Megabyte revised semi-annually = 6,773

Total revised annually = 13.5 Gbytes

* Replaces 37 Sectional Charts (40" X 55").
** Replaces one U.S. Gulf Coast Chart (40" X 55").
\+ Data scanned at 500 DPI and then reduced to 250 DPI for storage in the Super Sectional Chart (SSC) database.

Note: only one-sixth of the SSC database will be revised each month; however, the entire SSC database must be recompiled each month and provided to the FAA for a total of 81 gigabytes processed each year.

TABLE 2

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GENERALIZED CARTOGRAPHIC PROBLEM MATRIX FOR MAJOR AAS PRODUCTS

Problem	Terminal Charts	Controller Charts	Visual Sectional Charts
Reduction	Yes	Yes	Yes
Magnification	No*	No*	No*
Text	Yes**	No	Yes**
Symbols	Yes+	Yes+	Yes**
Screen Format	Yes	No	No
Projection Warping	No	Yes	Yes
Chart overlap	No	Yes	Yes
Color	No	No	Yes
Data Density	No	No	Yes
Update Cycle	Yes@	No	Yes@@

Definitions: Yes - indicates the existence of a problem
No - signifies that no problem is known to exist

* Up to 4X magnification with no problem
** Text is too small for distant viewing.
\+ Symbols must be simplified.
@ 56 day cycle with a 28 day update
@@ Only 4 to 7 of the 37 Sectional Charts are revised and inserted into the superchart database each month.

TABLE 3

Text Size

The most critical cartographic challenge is text size. Arthur Robinson (Robinson, 1978) states that "...3-point type is the smallest, just recognizable type at usual reading distance. Normal vision is, however, a misnomer; it certainly is not average vision. It is safer to generalize that probably 4-point or 5-point type comes closer to the lower limit of visibility for the average person." Usual reading distance is defined as approximately 18 inches for people with normal vision, or about one-half the distance from the Auxiliary Display to the controller. Since NOS charts required to support the AAS contain 5-point to 7-point type, some information will not be visible to the air traffic controller on the Auxiliary Display. The controller will have to magnify the image by a factor of 2 or the size of the smallest type doubled.

Magnification

Magnification of the AAS chart data in the 2X to 4X range will be required for viewing on the Auxiliary Display. However, magnification beyond 4X will cause loss of clarity and an increased emphasis of the relative importance of minor features. In addition, the viewer incorrectly may attribute a higher degree of accuracy to the magnified data because of its larger scale. Magnification may also create another problem. As controllers magnify portions of the charts, they may require increased feature identification (i.e., more road identification, closely spaced river names, etc.) to orient themselves on the chart.

<u>Reduction</u>
Reduction of AAS chart data will result in undesirable and inescapable changes. Adjacent discrete items will become crowded, clarity will be reduced, and there will be an increase in the visual significance of the general to the detriment of the specific. Modifications in layers of vector data will alleviate some reduction problems, but even a 0.5X reduction will render some type illegible. Reduction of pixel data will be harmful--symbols and text will become unrecognizable at reductions beyond 0.67X.

<u>Symbols</u>
Digital pixel symbols will be exact copies of the paper product symbols from which they are scanned and will be satisfactory at reductions of less than 0.67X. Vector symbols will be retrieved from libraries by software, and may be manipulated. Since AAS parameters require that a data screen be drawn in 4 seconds or less, vector symbols must be designed for efficient display and must closely resemble corresponding paper product symbols. Symbol cells should have few vertices and employ area fills whenever possible. Line strings must be used in lieu of circles and arcs, since AAS protocol prohibits use of arcs in symbol generation (Thornburg, 1988). Simplified symbols will be employed and reductions less than 0.67X will be acceptable.

<u>Display Screen Format</u>
Some text on the 5" x 8" (vertical format) TPP's will not be legible on the Auxiliary Display and must be magnified. However, if magnified enough to be legible, the TPP will not properly fit the 10" x 12" landscape format of the Auxiliary Display (Weissberg, 1993). Therefore, 7400 TPP's must be reformatted.

<u>Chart Overlap and Projection Warping</u>
The format of the existing Controller and Sectional paper charts will be redesigned to eliminate overlap. ACD has developed a super chart concept in which two seamless charts, one for Sectional and one for Controller Charts, cover the continental U.S. Each chart uses the same projection parameters. Overlaps will be eliminated and data mathematically warped to fit the 1:500,000 scale super chart projection. Data will be stored in 36" X 36" panels (Buja, 1993).

<u>Color</u>
Vector data will be displayed in 64 colors identical to those on

the paper products with one exception; high and low airspace data will be differentiated by color to allow use of a single controller chart for both levels. The appearance of the digital Sectional and U.S. Gulf Coast Charts will differ slightly from that of the paper charts since only 64 colors will be used for pixel data. Attempts failed to save additional computer memory by reducing the number of colors to 32. (Buja, 1993).

Density and Processing of Scanned Data

For accurate chart portrayal, visual chart data will be scanned at 500 DPI to provide adequate data for such destructive manipulations as rotation, smoothing, and color reduction. The data will be stored at 250 DPI, provided to the FAA at 125 DPI, and displayed at 100 DPI.

Data Updating

Every 56-day cycle the entire Controller Chart database will be updated and reissued to the FAA. The TPP database and indices will be updated in a more complicated process. Every 56-day cycle all 7,400 TPP's must be reissued when 1,000-1,300 procedures are revised. At mid-cycle, a Change Notice effecting 30-100 procedures must be inserted into the database, requiring revision of the database and indices, and reissue of the entire set of 7400 TPP's.

The Sectional Charts present a difficult updating problem. Since the suite of 37 paper charts is on a 6-month revision cycle, 4 to 7 charts are revised and reissued each month. These charts will be scanned and the resulting pixel data reduced from 500 to 250 DPI, warped and rotated, and their colors reduced. The data will be scissored and edge fit into 36" x 36" panels, and finally, the entire database partitioned, inserted into the proper ARTCC data set at 125 DPI and provided to the FAA.

Staffing to Process Data

The data capture, systems support, maintenance, quality control, and processing of over 80 gigabytes of raster data and nearly 58 gigabytes of vector data annually will require a staff of 28, half for the cartographic effort and the remainder to provide systems, programming, and computer support.

CONCLUSION

The NOS faces many cartographic challenges to supply digital charts in support of the AAS. Data handling will be a staggering task. The capture, manipulation, and formatting of vector and pixel data for the FAA will involve processing several gigabytes of data each month. Cartographic generalization and text/symbol depiction will present the greatest cartographic challenges in the AAS project. The NOS must redesign present products to meet these challenges and will work with the FAA to train the air traffic controllers about the inherent limitations of the cartographic deliverables for the AAS.

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