Generic Airspace Survey

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This paper reports on an extension of generic airspace research to explore the amount of memorization and specialized skills required to manage sectors with specific characteristics or factors. Fifty-five retired controllers were given an electronic survey where they rated the amount of memorization or specialized skills needed for sixteen generic airspace factors. The results suggested similarities in the pattern of ratings between different areas of the US (East, Central, and West). The average of the ratings for each area also showed some differences between regions, with ratings being generally higher in the East area. All sixteen factors were rated as moderately to highly important and may be useful for future research on generic airspace, air traffic controller workload, etc.

Nomenclature

ANOVA = Analysis of Variance
ARTCC = Air Route Traffic Control Center
CC = Cognitive Construct
CD&R = Conflict Detection and Resolution
CIT = Controller Information Tool
FAA = Federal Aviation Administration
ICF = Integrated Control Facility
KSA = Knowledge, skills, and abilities
NASA = National Aeronautics and Space Administration
TRACON = Terminal Radar Control Facility

I. Introduction

Generic sectors are defined as segments of airspace in Federal Aviation Administration (FAA) Air Route Traffic Control Centers (ARTCCs) that controllers could manage without significant specialized training or experience, beyond what they would normally acquire to become certified. Generic airspace is part of the Next Generation Air Transportation System (NextGen) vision.[1]

The generic sector concept would apply to low complexity sectors in high altitude airspace. It may also encompass sectors with moderate traffic and complexity, given that limited local knowledge and specialized skills are required. An ability to identify and provide generic sectors could be helpful when facilities redesign or reorganize the airspace in the NextGen timeframe. The goal of this research was to identify and explore techniques that could be considered when creating or identifying generic sectors.

The FAA is developing plans to reconfigure the US airspace and replace the facilities that control it.[2] There are discussions about moving from 20 ARTCCs and over 50 Terminal Radar Approach Control (TRACON) facilities to six Integrated Control Facilities (ICFs). An ICF would combine en route and terminal operations and include a modern, open floor plan, enhanced amenities, and improved training capabilities.

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In the ICFs, it is expected that lower altitude sectors near airports will continue to be complex, requiring special procedures, routings, altitude restrictions, etc. However, at or above 24,000 feet (FL240), aircraft will mostly be in straight and level flight and controllers will primarily be keeping traffic separated and dealing with weather issues. It may be that some of this airspace could be classified as generic. Therefore, it is important to identify characteristics (or factors) that may be present in sectors that would make them difficult to manage (and so "non-generic"). There has been extensive research on sector complexity factors that generate controller workload,[3] but very little investigation of factors that necessitate special knowledge and skills to manage airspace.

II. Background

It is evident that the FAA may be moving toward large facilities that will hold many more sectors than the current ARTCCs and TRACONs. The existing restrictions that limit controllers to working six to eight sectors in an area of specialization could constrain the flexibility and staffing of the ICFs. However, generic airspace research, in preparation for a NextGen ICF environment, can provide technology and methods that may increase the number of sectors controllers can manage.

The first area of benefit results from systems that are either anticipated to be in place for NextGen, or have been developed as part of generic airspace research. DataComm and conflict detection/resolution (CD&R) are automation tools that should reduce controller workload and errors. They may also lessen the amount of information that controllers must remember. For example, DataComm obviates the need to memorize sector frequencies when initiating handoffs.

Research on generic airspace by the National Aeronautics and Space Administration (NASA)[4,5,6] and MITRE[7,8] has resulted in the development of on-screen displays, such as the Controller Information Tool (CIT), that provide essential information to controllers so that they do not have to rely on memorization as much as in today's system. These workload reduction and safety tools can help controllers manage a larger number of sectors, thus supporting staffing flexibility in ICFs.

The second area where generic airspace research may be of benefit is the identification of sector complexity factors that can be considered when selecting or designing sectors. Previous work has assumed that generic sectors must be, by definition, simple in terms of traffic, procedures, and events (e.g., weather). Certainly, simple sectors could be considered generic in that controllers could manage traffic without extensive local knowledge. Data that are needed could be supplied by a CIT-type system.

Other sectors may seem more complex because they possess certain features, such as military traffic or a mix of aircraft types (e.g., turboprop and jets). However, if operating such sectors is included in a certified controller's abilities, and does not require much specialized (local) knowledge or unique skills and abilities, then these sectors could also be considered generic. A controller could work traffic in such sectors with a reasonable amount of additional memorization and skills.

If the generic sector concept can be extended from being constrained to simple sectors to also include up to moderately complex sectors, it could lead to a new approach to the current areas of specialization. Controllers in an ICF would be assigned to an area containing a larger set of sectors than is possible today. The challenge is to identify factors that would affect whether a sector can be considered generic.

III. Approach

Assuming the presence of DataComm, CD&R, CIT, and other tools, the following discussion focuses on the amount of information and skills controllers have to learn to manage a sector. To address this, NASA identified a set of 16 complexity or generic airspace factors, based on prior research. These were incorporated into an online "Generic Airspace Survey" that had two "cognitive constructs" (CCs): memorization and skills. These two constructs are related to the concept of "knowledge, skills, and abilities" or KSAs. KSAs are used to identify requirements for employment. For this study, we emphasized memorization (an aspect of obtaining knowledge) and specialized skills. (We omitted the "abilities" component, judging it to be closely related to skills in this context.) Each of the generic airspace factors may require some amount of memorization of sector data and/or specialized skills to manage traffic. By separating out these CCs, we hoped to better define the variables relevant to generic airspace.

In the survey, the same set of factors was used twice. The first part of the survey asked: "Assuming that the airspace is at or above FL240 and that the traffic density is moderate, please rate the amount of memorized information required to work sectors with the following characteristics." The second section asked: "Assuming again that the airspace is at or above FL240 and that the traffic density is moderate, please rate the amount of specialized skills required to work sectors with the following characteristics." The rating scales were 1 (low) to 5

(high) with an additional “not applicable” response option. The survey was given remotely (via the Internet) to 55 retired en route controllers.

Generic Airspace Survey Factors:

1. Limited number of flight levels
2. Many climbing and/or descending aircraft
3. Several nearby major airports
4. Many required procedures
5. Many Letters of Agreement
6. Several merging traffic flows
7. Several crossing traffic flows
8. Several conflict points ("hot spots")
9. Complex airspace structure
10. Limited maneuvering space
11. Frequent weather events that affect operations
12. High mix of traffic (e.g., capabilities, speeds)
13. Special Use Airspace
14. Many military flights
15. Many Traffic Management Advisories
16. Limited radio and radar coverage

IV. Results

In the analysis, the data were organized by the 16 generic airspace factors, two CCs (amount of memorization required and amount of specialized skills required), and geographical areas. With regard to the third element, the survey data were separated into three groups corresponding to the area of the US where the retired controller had last worked. The following table shows the ARTCCs that were delegated to each area (East, Central, and West). There were 20 respondents from the East area, 18 from Central, and 17 from West for a total of 55. (Not all facilities were represented in the responses.)

Table 1. List of en route facilities and locations.

Facility	Center	Location
Alberquque	ZAB	Central
Denver	ZDV	Central
Fort Worth Center	ZFW	Central
Houston	ZHU	Central
Indianapolis	ZID	Central
Kansas City	ZKC	Central
Salt Lake City	ZLC	Central
Memphis	ZME	Central
Minneapolis	ZMP	Central
Cleveland	ZOB	Central
Chicago	ZAU	East
Boston	ZBW	East
Washington	ZDC	East
Miami	ZMA	East
New York City	ZNY	East
Atlanta	ZTL	East
Jacksonville	ZJX	East
Los Angeles	ZLA	West
Oakland	ZOA	West
Seattle	ZSE	West

The first data set (amount of memorization required), with the three geographic areas broken out, is shown in Figure 1. The generic airspace factors were sorted and displayed by the average score (taken across the three areas), from highest to lowest. This provides a graphical indication of the relative importance of the factors. The range of individual mean scores was between 2.8 to 4.1 (out of 5) in the amount of memorization needed. The results are in the medium to high range, suggesting the importance of memorization for these airspace factors and areas.

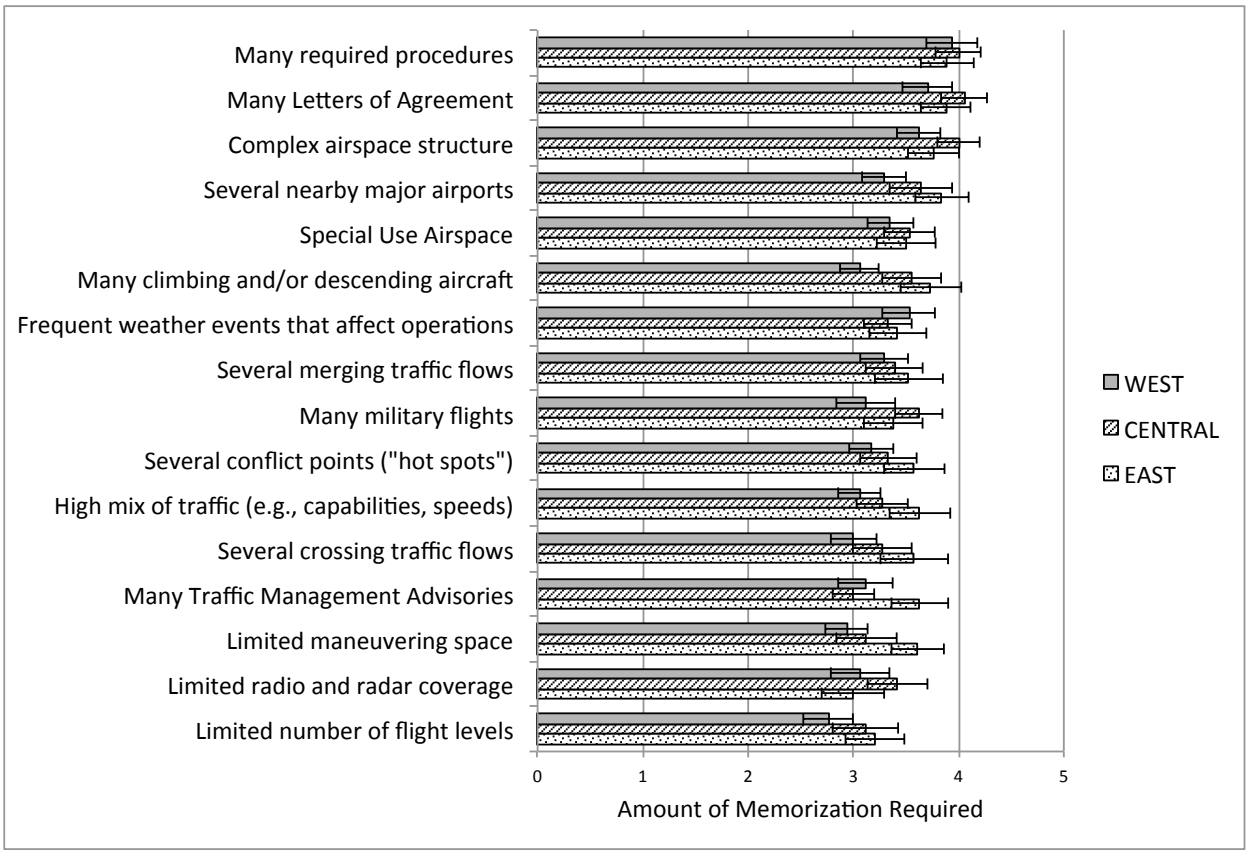

Figure 1. Amount of memorization required for each factor sorted from highest to lowest based on average ratings across the three geographical areas. (The error bars show standard error of the mean.)

The second data set (amount of specialized skills required), with the three geographic areas separated out, is show in Figure 2. The generic airspace factors were again sorted from high to low by the average score. Figure 2 presents a graphical depiction of the possible relative importance of the factors. The range of mean scores for this question was from 2.7 to 4.2. These results are in the medium to high range, suggesting the importance of specialized skills required for these airspace factors and areas.

Although the two figures show apparent differences between the generic airspace factors for each question, it was not possible to evaluate this by conducting statistical testing between all factors for all geographical areas. Therefore, the rankings implied in Figures 1 and 2 must be considered tentative. The error bars suggest that meaningful differences may not exist between many of the factors and areas.

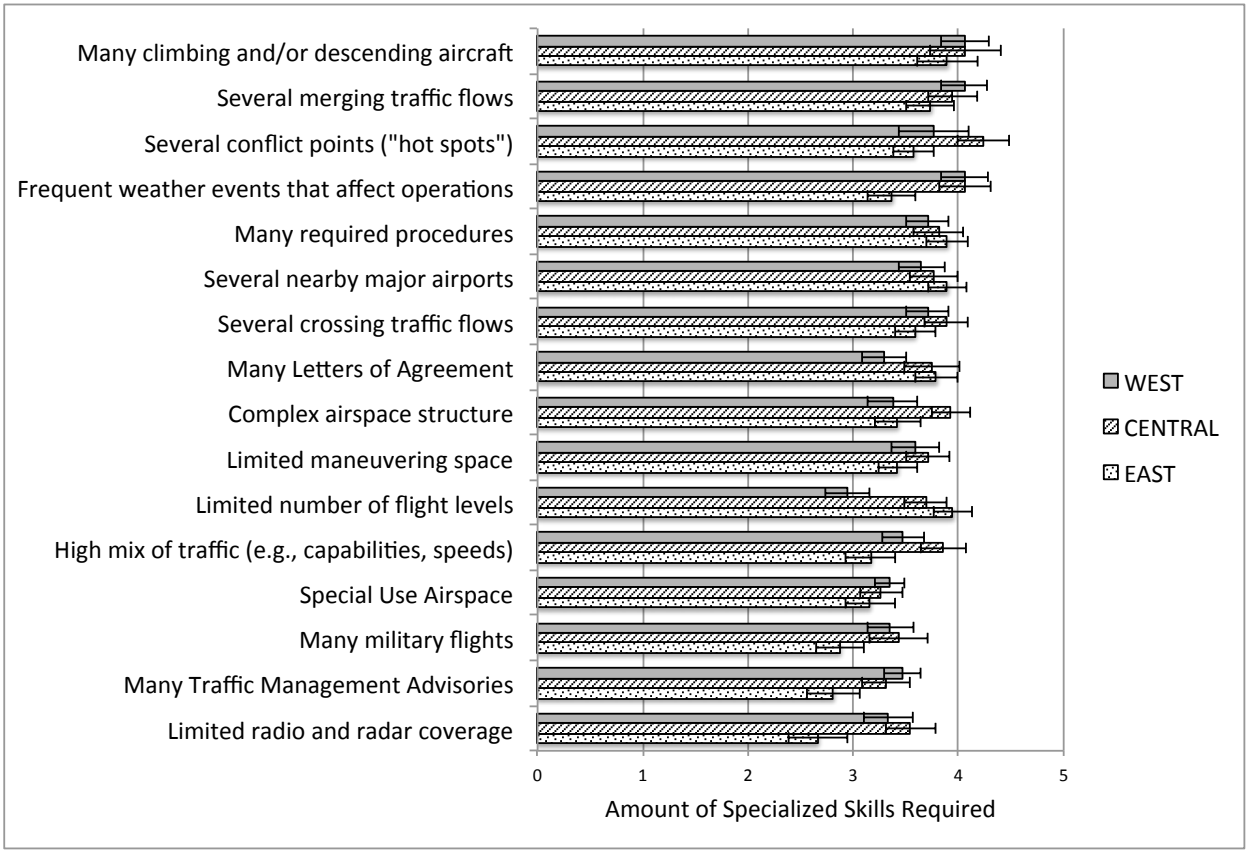

Figure 2. Amount of specialized skills required for each factor sorted from highest to lowest based on average ratings across the three geographical areas. (The error bars show standard error of the mean.)

Pearson product-moment correlations were computed between the three sets of factor ratings for the two CCs. This was to determine if the pattern of ratings between each pair of areas (East versus Central, Central versus West, and East versus West) were related. Statistically significant correlations were obtained for each CC, as shown in Table 2.

Table 2. Correlations between the three pairs of areas for memorization.

Areas	Correlation	Significance
East & Central	0.523	0.038
Central & West	0.804	0.000
East & West	0.565	0.022

Table 3. Correlations between the three pairs of areas for specialized skills.

Areas	Correlation	Significance
East & Central	0.781	0.000
Central & West	0.610	0.000
East & West	0.757	< 0.0001

The correlation results show that the patterns of ratings between the areas for each CC are not identical, but similar overall. Controllers rated the importance of the factors generally the same within each CC. However, a correlation of the ratings (averaged across areas) between the CCs was not statistically significant, indicating that the pattern of ratings between the CCs is not similar.

An Analysis of Variance (ANOVA) was completed to determine if the averages of the memorization ratings across all factors varied between the three geographical areas. There was a significant difference between the averages $F(2, 45) = 5.07$, $p = .010$. Tukey post-hoc comparisons between the three means indicated that the East ratings ($M = 3.57$, $SD = 0.23$) were significantly higher than the West ratings ($M = 3.25$, $SD = 0.30$), $p = .031$. Comparisons between the other groups were not statistically significant at $p < .05$.

An ANOVA was also completed to determine if the averages of ratings for specialized skills differed between the three areas. For these data, there was a significant difference between the average ratings $F(2, 45) = 3.49$, $p = .039$. Tukey post-hoc comparisons between the three means indicated that the East ratings ($M = 3.77$, $SD = 0.26$) were significantly higher than the Central ratings ($M = 3.45$, $SD = 0.40$), $p = .031$. Comparisons between the other groups were not statistically significant at $p < .05$.

These results show that the average ratings for East, Central, and West tended to be dissimilar, except in the cases noted above. Out of the six possible comparisons, there were statistically significant differences between two pairs of areas. For memorization questions, the East ratings were higher than West and for specialize skills questions, East was higher than Central. Although the differences are not uniform, this does suggest that airspace in the ARTCCs in the eastern part of the US tends to be seen as requiring more memorization and specialized skills than other areas of the country.

V. Conclusion

The generic airspace factors used in this study were derived from prior research in the area. Over time, various sets of factors that could help account for sector complexity or controller workload have been identified and evaluated. The survey data reported here confirms the importance of these factors. What is new is the focus on two separate CCs involved in managing airspace: amount of memorization and specialized skills.

The overall results from a survey of 55 retired controllers show that the sixteen generic airspace factors for both memorization and skills were rated from moderate to high in importance. While there were apparent differences in the rankings in Figures 1 and 2, statistical testing was not practical, and so the order may not be reliable.

However, for memorization and specialized skills, the patterns of ratings were related across the three geographical areas. Although there are probably differences on some factors for ratings between the areas (e.g., "Many climbing or descending aircraft" in Figure 1), the pattern of results was similar between East, Central, and West. The average ratings between the three areas were different in most cases. For memorization, East was higher than West and for specialized skills East was higher than Central. This might be expected since eastern US airspace is generally regarded as more complex and congested, thus requiring controllers to memorize more information and develop specialized skills.

The results of this work can be applied to research on generic airspace, sector complexity, skills, and other areas where there is interest on how airspace characteristics affect the memorization and specialized skills required in air traffic control. The responses from the survey confirm that the list of 16 generic airspace factors should be include whenever the characteristics of airspace and their effects on air traffic controllers must be considered.

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