Generic Airspace Research
Phase 5 Report

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Executive Summary

This research project is the fifth in a series that has focused on exploring the concept of "generic sectors." A generic sector is defined as one that can be managed by air traffic controllers without the need for extensive memorization of sector data or specialized skills. This Next Generation Air Transportation System (NextGen) concept could support a more flexible allocation of the controller workforce. Current Federal Aviation Administration (FAA) NextGen plans include generic sectors as part of the FAA's High Altitude Airspace Concept.

Previous generic airspace research has made use of a Controller Information Tool (CIT), which displays data a controller may need to work traffic in a specific sector. Also included were automation tools such as DataComm and conflict detection/resolution, which also support the generic concept. The current experiment was conducted at the NASA Ames Research Center and was designed to investigate the placement of the CIT display. The alternatives included "Standalone," with the CIT on a separate screen above the control position, and "Integrated," with the information directly accessible on the radar display.

The simulation laboratory research environment was Oakland Center sectors 30 and 33 combined. Following training on the CIT and automation tools, sixteen recently retired FAA controllers each worked two traffic scenarios using the two versions of the CIT. Each scenario ran for 50 minutes. The traffic consisted of 40% to 50% DataComm-equipped aircraft. Data were recorded on workload, frequency of access to CIT data, operational errors, CIT placement preference, and CIT usability.

Workload was assessed using a range of methods including observer ratings, on-screen entries, and post-run questionnaires. There was no significant difference between the Standalone and Integrated CIT conditions on any of the workload measures. However, the participants expressed a clear preference for the Integrated CIT. It reportedly allowed better situation awareness because the controllers could keep their focus on the traffic display.

Logs of CIT key usage showed that sector frequencies were accessed most often. Sector information was also called up, but less often. Route keys (e.g., San Francisco traffic flows) were used occasionally, and mostly at the beginning of a run. Controllers accessed CIT data about the same number of times in each condition. On average, the CIT information was removed from the screen (turned off) more often in the Integrated condition, perhaps to control display clutter. Suggestions for improvements to the CIT user interface included making the fonts larger, combining the frequency and sector keys, and removing the time out feature of the CIT data.

There were a few operational errors during the runs, but no differences (in number of errors) between the two CIT versions. However, controller scan did seem to play a role in some of the Standalone errors. Some losses of separation were attributed to difficulties using the automation tools.

The conclusions of this study are that controllers strongly preferred the Integrated version of the CIT over a separate, Standalone screen. The primary reason for this seemed to be that it allowed them to remain focused on the traffic situation, whereas the Standalone CIT required them to move their attention away from the radar presentation for short periods. Further research should identify the information needed by controllers and consider how to integrate the CIT into operational systems.

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1. Introduction

In the current air traffic management system, sectors of airspace have unique designs, labeling, and associated procedures. These characteristics have evolved over the years to accommodate navigation, traffic flow, and safety requirements. However, the result is that controllers may need extensive training on sectors they manage, which can make the transfer of staff between areas or facilities difficult. As part of the Next Generation Air Traffic Control (NextGen) High Altitude Airspace Concept,[1] the Federal Aviation Administration (FAA) has been exploring whether some areas of high altitude, en route airspace can be designed to be "generic," such that controllers could work more sectors without significant additional training.

There are two approaches that have the potential to reduce the training time required for controllers to manage airspace. The first is to redesign the airspace such that its shape, route structures, labels, procedures, etc. do not require extensive memorization and specialized skills. This approach may make at least some proportion of sectors easier to work.

A second approach is to create automation and decision support tools that provide sector data and help to manage traffic. In line with this strategy, a Controller Information Tool (CIT) has been developed that displays necessary sector and traffic flow details. This should reduce the time required to learn and adapt to a sector by providing information, so that less has to be memorized. Preliminary tests of the CIT in prior research studies demonstrated that it was valuable in assisting controllers to work sectors of unfamiliar airspace.

Along these same lines, NASA has also been experimenting with automation tools such as DataComm and conflict detection/resolution (CD&R). These applications reduce the amount of data a controller has to remember and skills that must be acquired by automating such procedures as handoffs and transmission of route changes. They also reduce workload by scanning for conflicts and assisting with resolutions solutions.

In the following sections, past CIT research efforts are briefly described, followed by current study objectives. Each previous simulation consisted of a "phase" that examined the CIT and automation tools in support of generic airspace.

1.1. Past Research

The intent of the generic airspace task is to identify sector design features, information, and tools that will enable controllers to learn and manage their airspace. These could be used to help controllers move between sectors, adapt to boundary changes, or respond to alterations in traffic flow or airspace requirements, as determined by algorithms or procedures driven by traffic volume or sector complexity measures.

To begin understanding the functionalities of automation tools required for this task, four complementary generic airspace studies, called Phases 1 through 4, were conducted to explore different facets of CIT use. For Phase 1, we developed an evaluation in the context of present-day automation and procedures, using the NASA Multi Aircraft Control System (MACS) air traffic control simulator[2] and a CIT for a single sector. For Phase 2, we modified the information on the CIT based on user input from Phase 1, added a second sector, and applied mid-term NextGen automation tools to create a future air traffic management environment.

In Phase 3, we evaluated the generic airspace concept by rotating controllers through five, contiguous, real-world sectors, four of which they had no prior familiarity and where they relied on the CIT for sector information.[3] For Phase 4, we evaluated controllers, unfamiliar with a single generic sector, managing traffic under four different traffic scenarios that included off-nominal conditions.[4] The overall results from these studies showed that controllers were able to work traffic in unfamiliar sectors with acceptable safety and workload with the aid of the CIT, DataComm, and CD&R, supporting the generic airspace concept.

2. Current Study Objective

For the Phase 5 study, two versions of the CIT were developed to evaluate a Standalone (separate or off-screen) versus an Integrated (on-screen) presentation. The purpose of the study was to examine the appropriate placement and functional requirements for the information tool.

The Standalone CIT display was located above the controller's radar screen while the Integrated CIT incorporated the information into the controller's radar display. The Integrated CIT had the advantage of allowing the controllers to access the sector data without taking their eyes off of the radarscope. However, too much data on the radar display could result in visual clutter. In contrast, a separate screen could allow a significant amount of information to be shown without the clutter issue, but the controllers might find the display distracting when they became busy managing traffic.

Both CIT versions were designed as methods for reducing the memorization and training required to manage air traffic in mid-term, NextGen airspace. All problems simulated a mixed communications environment of DataComm-equipped and voice-only aircraft. Details of the experimental design are described in the next section.

3. Method

3.1. Software and Equipment

For the study, two versions of the CIT (Standalone and Integrated), designed with identical keys, displayed information for the combined sectors 30 and 33 in Oakland Center (ZOA). The Standalone CIT was mounted above the main radar screen. (See Figure 1.)

Each CIT had on-screen buttons (or keys) that accessed different CIT views. (See Figures 2 and 3.) The same trackball was used to control both the main radar display and the CIT. The available CIT views included:

1. Special use airspace (SUA).
2. Radio frequencies.
3. Sector names and altitudes.
4. Ground aids: Locations and names of fixes and NAVAIDs.
5. Major traffic flows for Departures (DEP), Las Vegas (LAS), Oakland (OAK), Seattle (SEA), San Francisco (SFO), and San Jose (SJC), showing routes, traffic direction, and exit altitudes.

The keys allowed participants to call up these data as needed for controlling traffic. The displayed information only persisted for 15 seconds before disappearing. The information was automatically "toggled off" for experimental purposes, in order to record the number of times that the participants needed specific CIT data, and "toggled" it back on. Participants could manually turn the CIT off prior to 15 seconds.

Figure 1. Standalone CIT.

The only exception was the SUAs, which did not automatically disappear. The SUA key was designed to be persistent to coincide with how the SUAs are depicted on the controllers' displays in today's operations.

Figure 2. Standalone CIT keys.

Figure 3. Integrated CIT keys.

Figures 4 and 5 illustrate the Standalone and Integrated CITs. Each CIT was programmed with identical information. Sector frequencies and route transition altitudes were adjusted for each run to minimize the effect of the participant's ability to learn the information on the different CIT versions.

The CIT assessment employed the air traffic control simulators resident in the Crew-Vehicle Systems Research Facility Air Traffic Control Laboratory. Located in Building N257 at the NASA Ames Research Center, this laboratory has ten air traffic control positions. Using FAA en route consoles with 20" X 20" displays, the laboratory also has pseudo-pilot workstations and a voice communications system. It uses MACS to realistically simulate the FAA en route air traffic control Display System Replacement user interface. (See Figure 6 for the laboratory layout.)

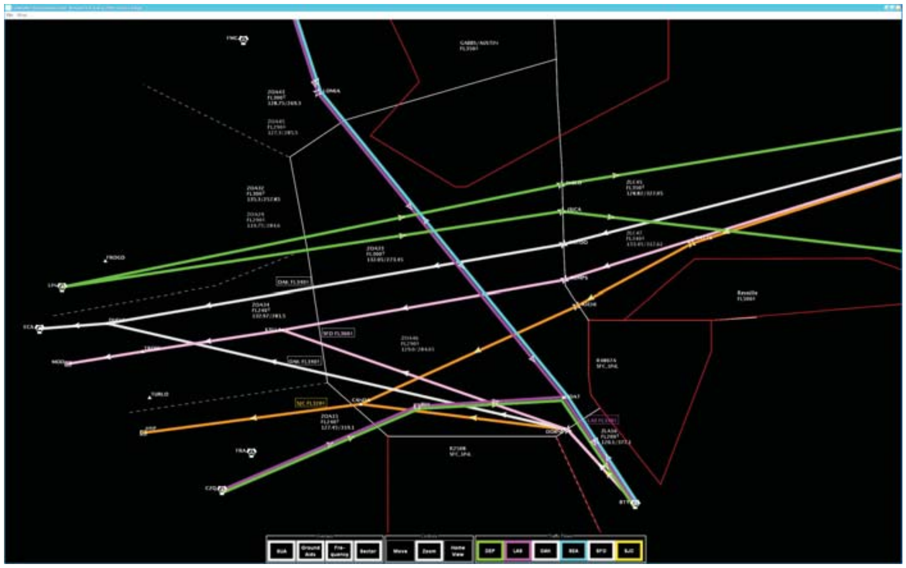

Figure 4. Standalone CIT display.

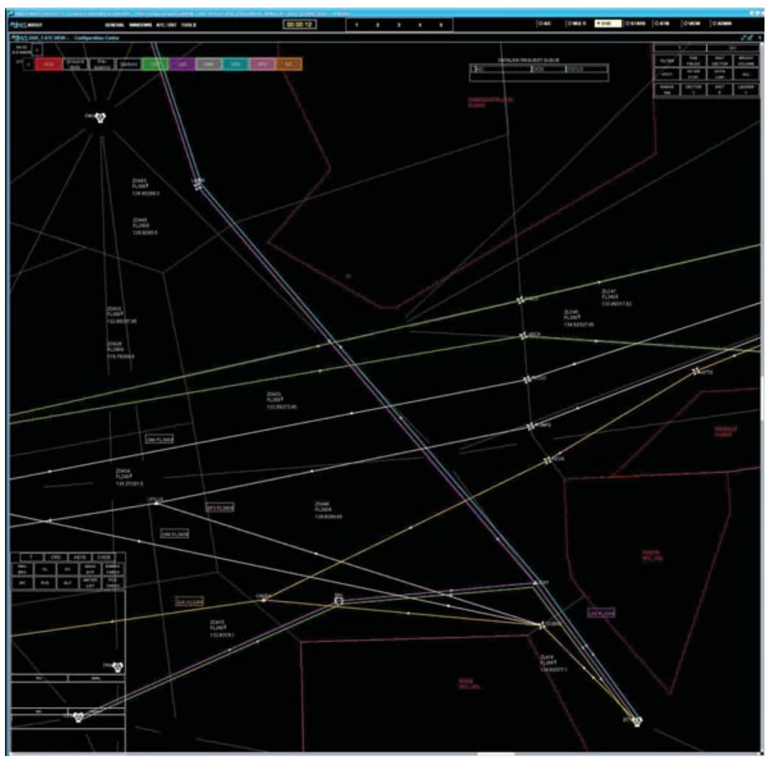

Figure 5. Integrated CIT display.

MACS was configured to provide controller-pilot DataComm for clearances (with voice backup) and CD&R (with manual resolution capability) for DataComm-equipped aircraft. For non-DataComm equipped aircraft, controllers were able to use trial planning with manual CD&R and had an interface for entering data into MACS to update flight information, but communicated clearances using voice.

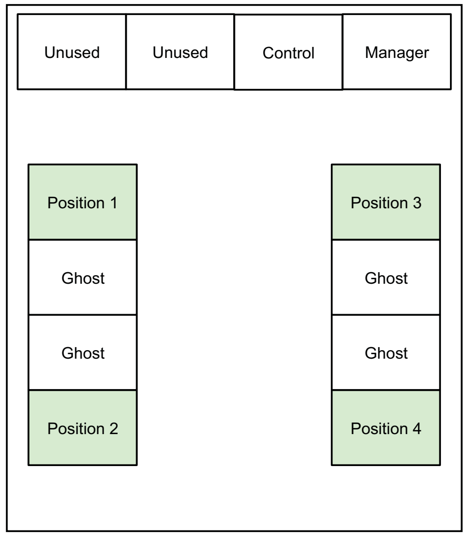

Figure 6. Air traffic control laboratory layout.

3.2. Airspace and Traffic Scenarios

The simulated airspace consisted of a single sector, which was the result of combining sectors 30 and 33 in ZOA. Combined sector 30/33 is an en route sector on the eastern side of ZOA at FL240 and above. The major traffic flows consisted of arrival streams into SFO, OAK, and SJC airports and, to a lesser degree, departure streams from these airports, as well as flights to/from other destinations such as SEA or LAS. (See Figure 7.)

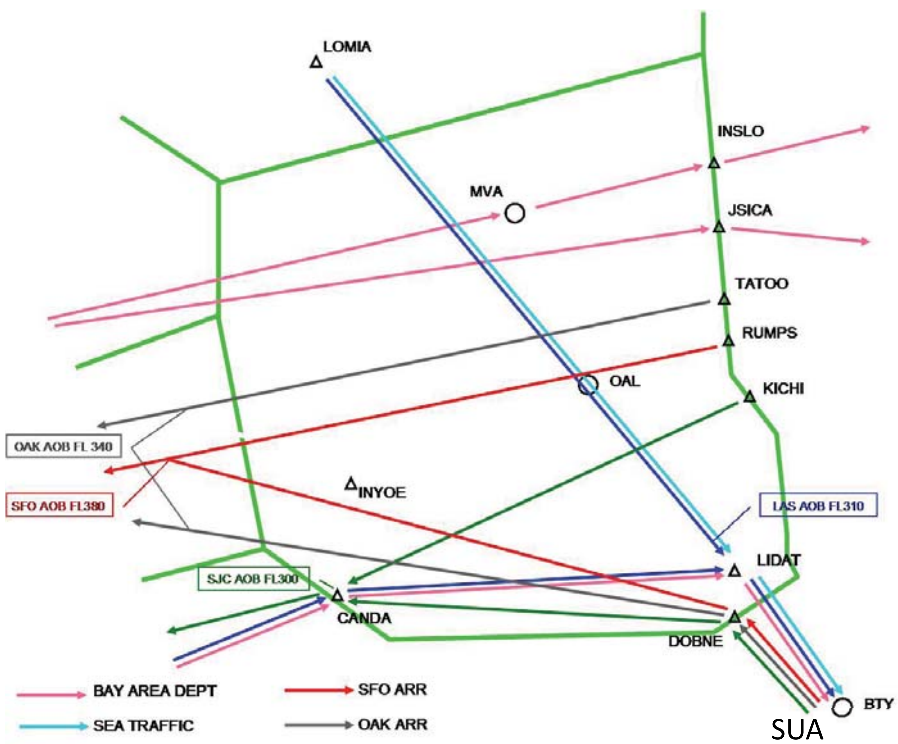

Figure 7. Major traffic flows in ZOA 30/33 combined.

Two traffic scenarios were created for this experiment. Each was based on actual ZOA traffic. The scenarios had comparable traffic patterns and traffic loads that approximated the current Monitor Alert Parameter (MAP) value of 20, which applied to ZOA 30/33 combined.[5] Each scenario ran for 50 minutes. The traffic consisted of 40% to 50% DataComm-equipped aircraft. Routes were designed with the assumption that all flights were Automatic Dependent Surveillance Broadcast-equipped and made use of published waypoints as opposed to employing the ground-based, jet route structure. One additional scenario was created for training.

3.3. Participants

Sixteen recently retired (within three years) air traffic controllers were recruited as participants (four for each day of the simulation). The participants had the necessary skills to manage the sectors, although they had not worked the specific ZOA sector in the past. Four retired supervisory air traffic control specialists acted as observers. Eight pseudo-pilots assisted with managing the controls of aircraft within the simulation. All participants were paid for their time.

3.4. Experimental Design

The study was a within-subjects design with two CIT display conditions: Standalone and Integrated. It was conducted during a four-day period. On each day, four controller participants managed traffic in the ZOA sector. They worked in "parallel simulation worlds" in which they managed the same sector but in different experimental conditions and different traffic scenarios. Each participant conducted two data collection runs, one for each CIT condition, resulting in a total of 32 scenarios. The order of the runs was counter-balanced across the different conditions. (See Table 1.)

At the conclusion of the first day's runs, feedback from participants indicated that they needed more training on NextGen tools (DataComm and CD&R) to manage traffic in the scenarios. Based on this information, it seemed that the workload might be adequately managed with additional hands-on training without making changes to the traffic scenarios. Since modifying traffic scenarios at the last minute was undesirable, we added one hour of training for the remaining three days and excluded the day 1 data from our analyses. The data from the remaining twelve participants were included in the results.

Table 1. Experimental matrix for the Phase 5 study (repeated each day for four days).

	Participant 1	**Participant 2**	**Participant 3**	**Participant 4**
Run 1	Integrated CIT	Standalone CIT	Integrated CIT	Standalone CIT
	Scenario A	Scenario B	Scenario B	Scenario A
Run 2	Standalone CIT	Integrated CIT	Standalone CIT	Integrated CIT
	Scenario B	Scenario A	Scenario A	Scenario B

3.5. Procedures

The study was scheduled from March 8 to March 11, 2011. On each day, four controller participants attended a briefing on the experiment and on how to operate the automation tools in MACS (DataComm and CD&R). Each participant was assigned to a separate workstation and provided with a hands-on introduction to the CIT. On the second through fourth days, they were then presented with a 50 minute "tools training" traffic scenario. Controllers used the CIT (both Integrated and Standalone were available) to access sector data needed for managing traffic. This was followed by two runs to collect performance data.

Using a screen playback tool, controllers were then interviewed about how they dealt with each use of the CIT user interfaces. NASA staff also asked questions about the usability of the CITs. There was a final discussion at the end of the day. The daily schedule is shown in Table 2.

Table 2. Experiment schedule.

Time	March 8	March 9	March 10	March 11
0800 - 0900	Briefing	Briefing	Briefing	Briefing
0900 - 1000		Tools Training	Tools Training	Tools Training
1000 - 1030	Break	Break	Break	Break
1030 - 1130	Run 1	Run 1	Run 1	Run 1
1130 - 1200	Debrief	Debrief	Debrief	Debrief
1200 - 1300	Lunch	Lunch	Lunch	Lunch
1330 - 1430	Run 2	Run 2	Run 2	Run 2
1430 - 1600	Analysis	Analysis	Analysis	Analysis
1600 - 1630	Discussion	Discussion	Discussion	Discussion

3.6. Data Collection

Key metrics for the study were chosen to assess the CITs in order to evaluate their placement. Subjective measures included ease-of-use of each display type. The participants also provided feedback on whether they preferred the Standalone or Integrated CIT while working traffic. Objective CIT usage data were collected and compared between the display types to corroborate the results from the subjective preferences. Objective metrics, such as operational errors and controller workload, were also gathered.

The following is a list of dependent measures used for the CIT study:

1. On-screen Workload Assessment Keypad (WAK) input every five minutes.
2. Frequency of access to CIT data.
3. Camtasia screen recordings of the controller's MACS display to assess CIT usage and safety critical events.
4. Post-run questionnaires (workload and other measures).
5. MACS computer-recorded metrics (operational errors).
6. Post-experiment questionnaires.
7. Over-the-shoulder data collected by controller observers (including workload ratings and frequencies used for handoffs).
8. Post-experiment debriefing to collect additional information.

4. Results

The workload results are described first to establish the traffic situation that the controllers experienced. This may have had an impact on CIT use during the study. Due to the minimal training time allotted prior to data collection and the moderate to heavy traffic levels that were presented to the controller participants, they spent a large portion of the simulation runs at or near their maximum workload thresholds. After the workload results, the participants' preferences for the CIT location and usage are described in detail, followed by an account of various operational issues that resulted from the study.

Statistical tests were carried out on the data at the $p < .05$ level. Only the statistically significant test results are reported. Error bars on the graphs represent the standard error of the sample. Fisher's Least Significant Difference test was used for post hoc analyses.

4.1. Traffic Load and Controller Workload

Traffic level and complexity for this experiment were based on the MAP value for ZOA sectors 30 and 33 combined. This is the level of traffic at which ZOA Traffic Management receives an alert that traffic is approaching capacity for the sector.

The MAP, which has a value of 20 for the sector tested, is defined as the number of aircraft predicted to be in the sector at the same time. Both traffic scenarios were designed to provide traffic at or near the MAP value for the sector. Figure 8 illustrates the aircraft count for the two scenarios used in this study.

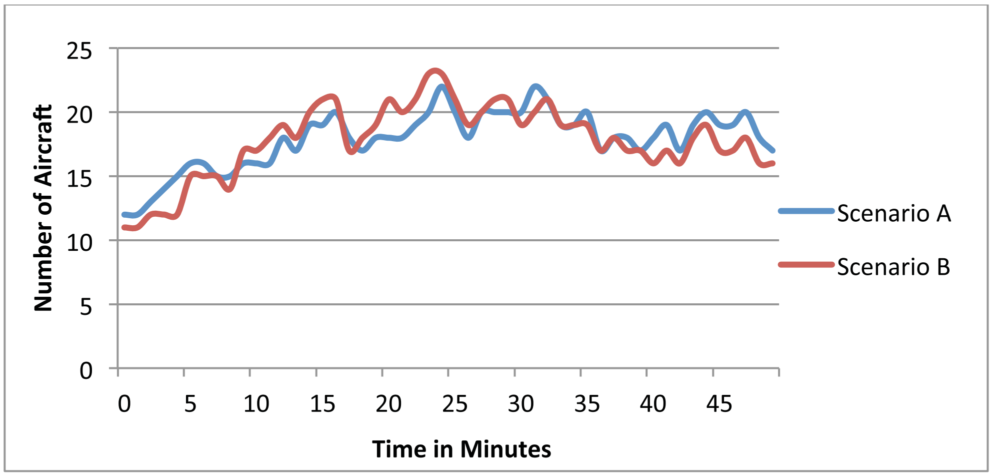

Figure 8. Number of aircraft in traffic scenarios A and B during the simulation runs.

The problems reached 75% of the MAP value six minutes into the 50-minute scenario. The traffic in the scenarios reached 90% of MAP 13 minutes after the start of the problem and continued to increase to 100% of the MAP or more about 17 minutes after starting the run. Traffic levels remained at moderate or greater levels for 88% of the scenario time. Traffic volume, control actions, and the lack of familiarity with ZOA 30/33 caused controllers to be more reactive than proactive in their approach to sector operations.

Controller workload was assessed using four methods: WAK ratings, participant post-run workload ratings of peak and average workload per simulation run, and over-the-shoulder assessments of controller workload by expert observers. (See Figure 9.) The ratings were on a scale of one (low workload) to five (high workload). WAK ratings were taken every five minutes during each simulation run. For all four methods of workload assessment, the workload values were similar between the Standalone and Integrated CIT conditions. Any differences were not statistically significant. (The WAK ratings from one participant were excluded from the analyses because s/he pressed the "1" key throughout the runs instead of values that reflected his/her workload.)

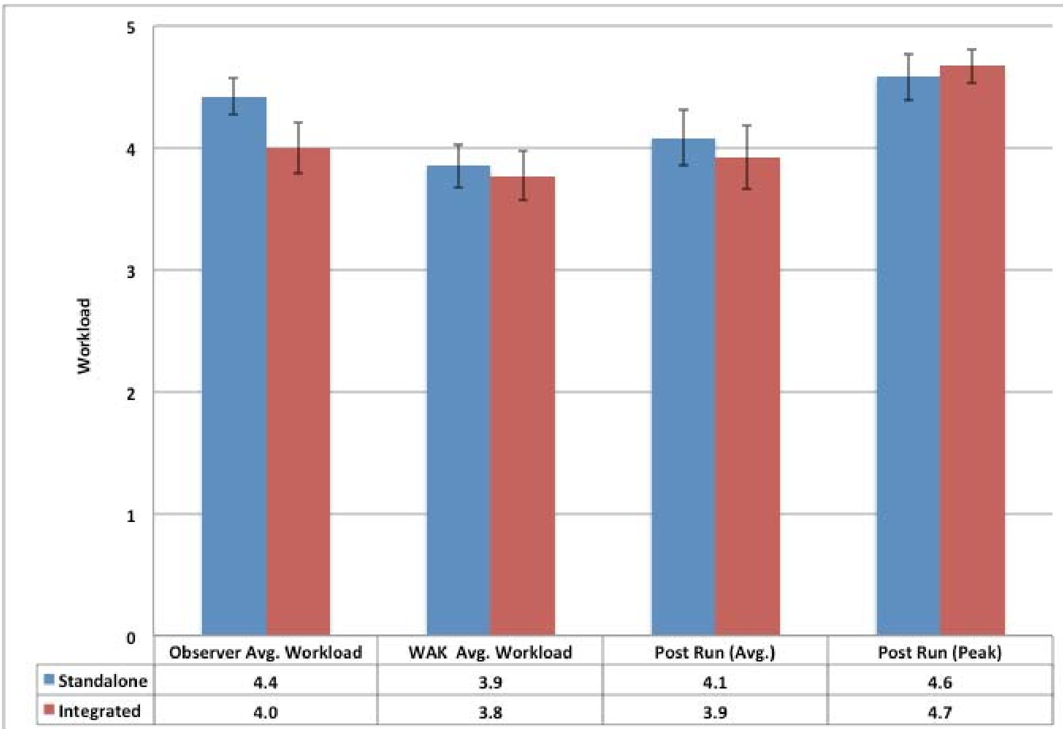

Figure 9. Workload data from the observers, the WAK, and post-run questionnaires.

4.2. Subjective Preference

Participants were asked to rate their preferences for the Standalone versus Integrated CIT after each simulation run. As shown in Figure 10, participants strongly preferred the Integrated over the Standalone CIT (Standalone $M = 1.7$, $SD = .89$, Integrated $M = 4.4$, $SD = .67$; $t(11) = 6.42$, $p = .001$).

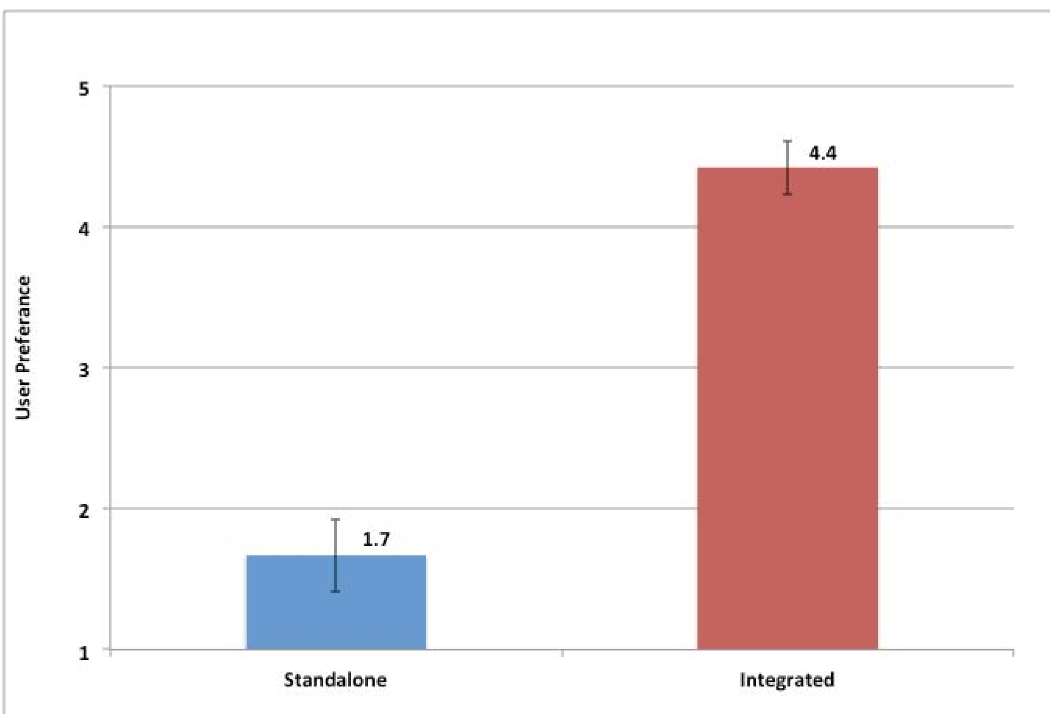

Figure 10. Controller CIT preference.

Additional questions were posed immediately after the completion of each run, following a video playback of the session when each CIT button was used. Each participant was asked "What did you use the [button name] for in this specific instance?" For each specific event, they were also asked, "Would you prefer the on-screen or off-screen CIT?" as well as, "Is there any additional functionality or information the CIT could have provided to you?"

Users generally preferred the Integrated CIT when responding to preference questions, and in these cases cited situational awareness as the reason. The Integrated CIT permitted the user to keep their focus on the radar display. Observations showed that the Integrated CIT also seemed to allow information to be accessed faster than in the Standalone CIT in terms of visual scanning and trackball inputs. There were a few instances where the participants preferred the Standalone CIT when they wanted information such as SUAs and ground aids that could potentially clutter the radar display.

4.3. CIT Use

The participants' ratings indicated a strong liking for the Integrated CIT. Expanding beyond preference, we examined the CIT usage to find out if differences occurred between the Standalone and Integrated CITs.

The usage data showed that the ground aids, DEP, and SEA keys were used rarely or not at all. Both CITs displayed the boundaries of active SUAs and provided altitude information in the SUA's label in red. Participants typically did not turn off SUAs and commented that the Integrated CIT made it easier to use SUA information.

The remaining keys (frequency, sector, and some route keys (LAS, OAK, SFO, and SJC)) were used about the same between the Standalone and Integrated CITs. Figure 11 illustrates the average number of times that keys were pressed to toggle the various CIT components on and off for the two conditions.

Statistical testing on the "key on" data from Figure 11 between the SUA, ground aids, frequency, sector, and route keys showed an overall main effect, ($F(4, 50) = 124.25$, $p = .0$). Post hoc testing demonstrated that frequency was significantly different from SUA, ground aids, sector, and route, and sector was significantly different from SUA, ground aids, and frequency, but not route.

There were no significant differences between the on and off usage for most of the keys. There appeared to be a large difference between the Standalone and Integrated conditions for frequency off and sector off. However, only the sector off results achieved statistical significance with Standalone CIT ($M = 1.4$) compared to the Integrated CIT ($M = 6.8$), ($t(22) = 2.72$, $p = .02$). These controller actions suggest that they wanted to remove some information on the Integrated CIT in order to minimize display clutter.

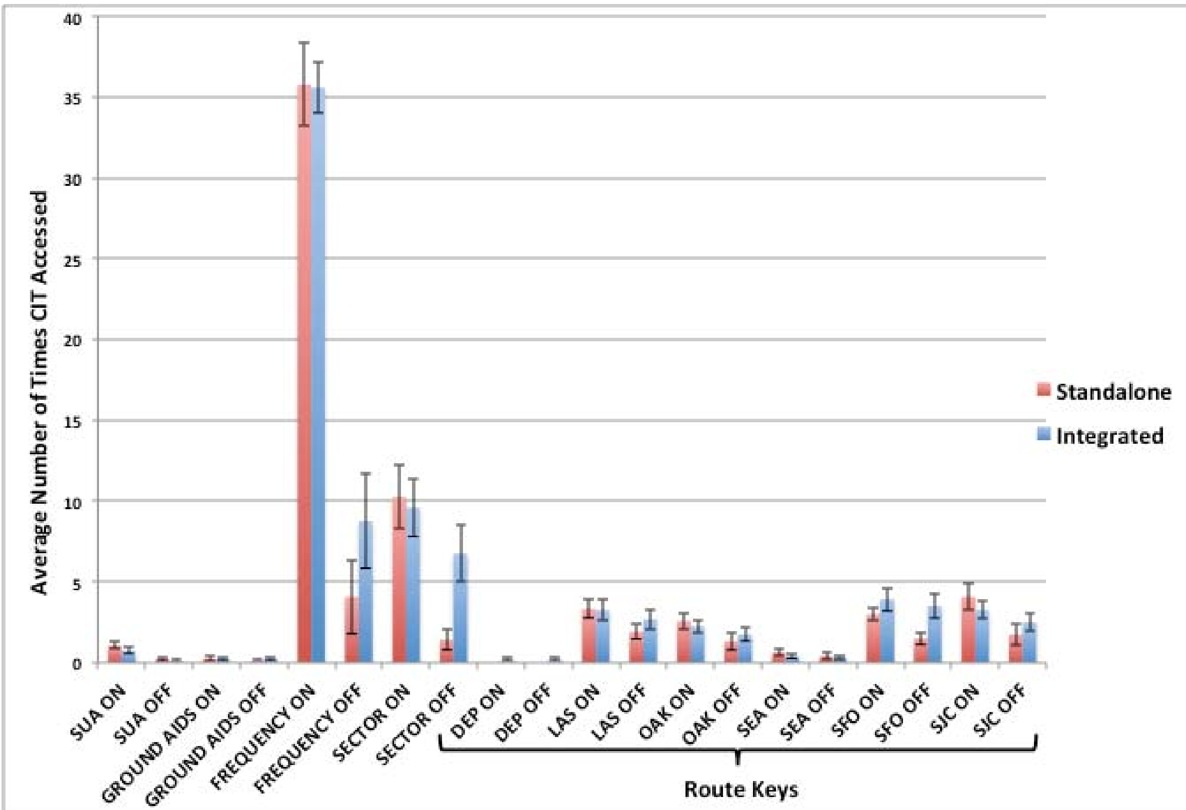

Figure 11. CIT key activity.

Frequency key selection increased rapidly at the beginning of the scenarios and reached a high usage level by 10 minutes into the scenarios. (See Figure 12.) This use level was sustained throughout the test period. Frequency key activity appeared to be driven by operational necessity.

Controllers required this information to successfully complete communication transfers for non-DataComm equipped aircraft prior to a hand-off to an adjacent sector. These frequency changes were required about 40 times in a scenario, creating a high demand for the data the key provided. Controllers indicated that the large amount of frequency data made the information difficult to retain in memory, which created the need to repeatedly access the key.

The sector data were accessed less often than the frequencies. The sector key was used to support the frequency key in the majority of selections. The participants primarily chose the sector key to verify the vertical stratification of adjacent sectors, such as Salt Lake Center sectors 45 and 47, whose vertical boundaries were at a different altitude than sector 30/33's vertical boundary. This key was used throughout the scenarios. (See Figure 13.) Controllers suggested that the sector and frequency keys be combined. (See Table 3.)

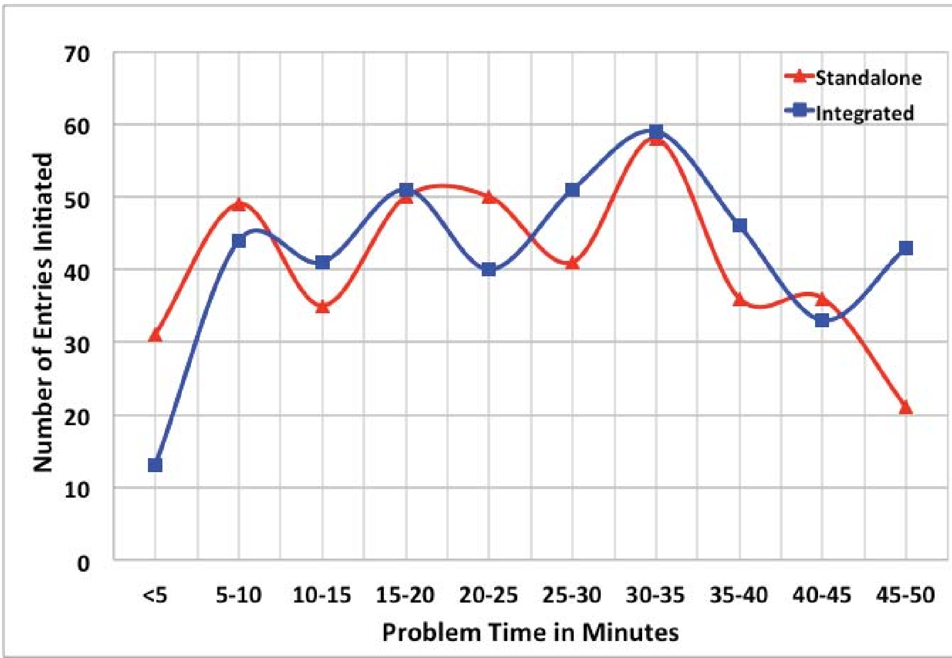

Figure 12. CIT entries: Frequency key initiated.

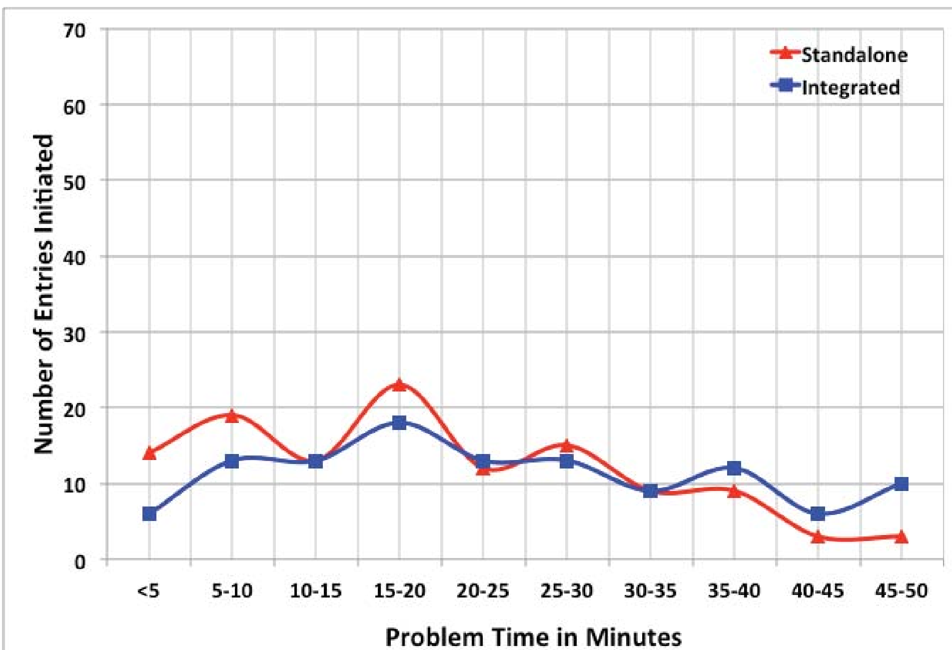

Figure 13. CIT entries: Sector key initiated.

While frequency keys were accessed throughout the simulation runs, the route keys were used heavily during the first five minutes of the scenarios and then at a much lower rate for the remainder of the time. (See Figure 14.) This suggests that the route information could be memorized within each scenario while the frequency information could not. Although the route information was complex in general, it seemed that the participants mainly needed to access specific data on altitude crossings on four of the six routes available on the CIT, which were easy to memorize.

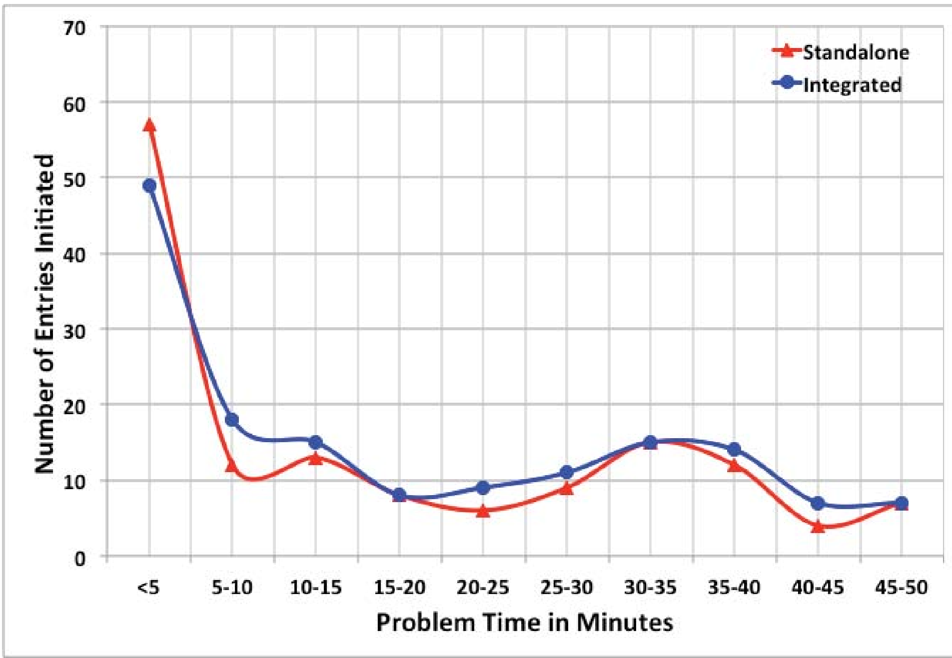

Figure 14. CIT entries: Route key initiated.

Figure 15 shows the percentage of time that the displayed data timed out at 15 seconds. Actively toggling off these data prior to the 15 seconds suggests that the participants wanted to minimize the display clutter caused by the data. In general, it appears that the keys in the Integrated display timed out less frequently (i.e., were actively toggled off more often) than the keys in the Standalone display. However, the differences were not statistically significant for the frequency and sector keys. The route keys were toggled off more often in the Integrated ($M = 20\%$) compared to the Standalone CIT condition ($M = 54\%$), ($t(11) = 4.74$, $p = .001$).

Figure 16 shows CIT key selections that were toggled on and off across different keys, averaged across the simulation runs. Although the participants preferred the Integrated CIT display, the results indicate that they accessed the information on these keys as often on the Standalone version. However, they actively toggled off the CIT information (rather than allowing it to time out after 15 seconds) more often with the Standalone CIT ($M = 12.7$) compared to the Integrated CIT ($M = 26.8$), ($t(11) = 3.79$, $p = .003$), presumably to minimize radar display clutter.

Table 3 represents the participants' feedback on how displays and ease of use could be improved. Responses were requested by key type. Controllers recommended that the frequency and the route keys be combined because the information supplied by these keys was often required simultaneously. The majority of other responses suggested improvements in visibility and operationally related data. Omitted and "No change required" responses are not included in this table.

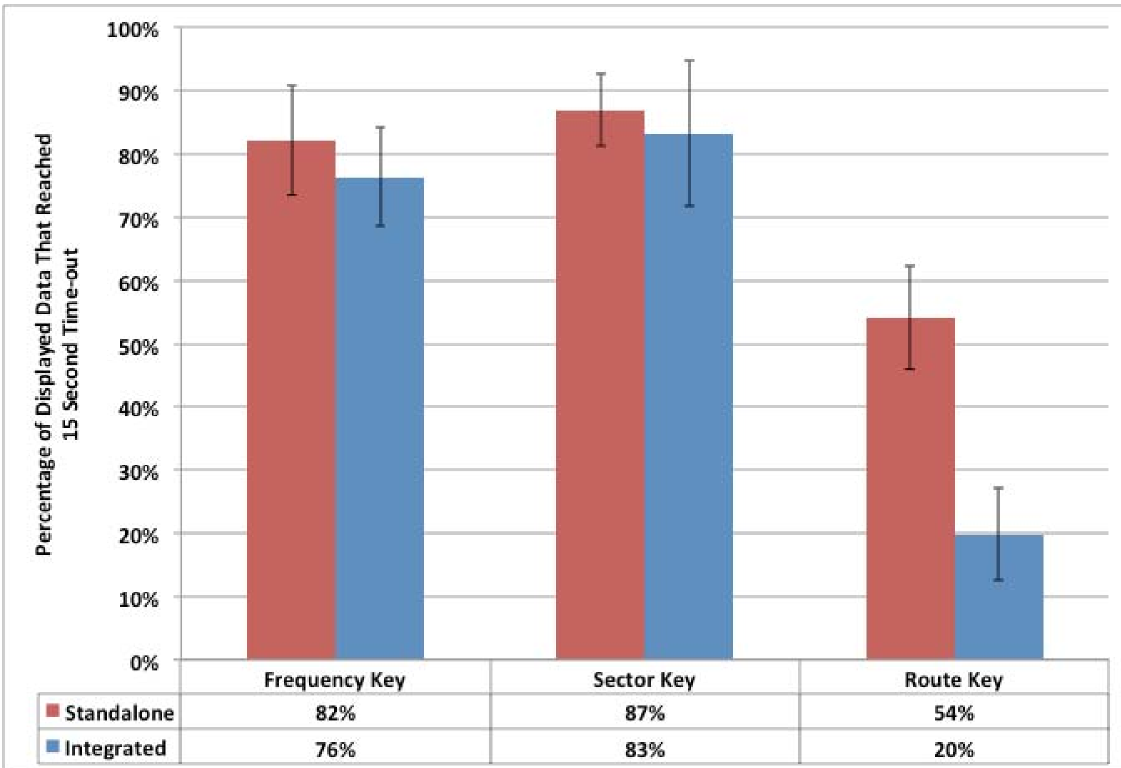

Figure 15. CIT time-outs.

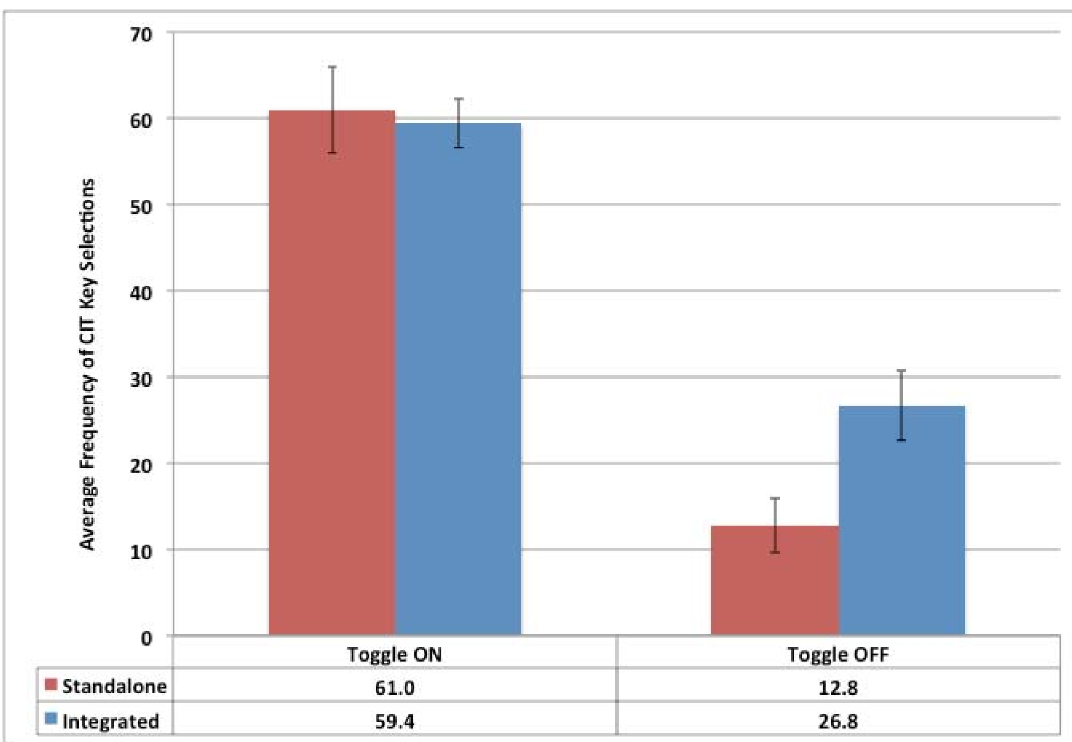

Figure 16. CIT key activity

Table 3. Number of participants per improvement recommendation.

Item	Frequency	SUA	Sector	Route
Larger font	3	1	2	
Configurable font	1			
Combine frequency and sector keys	6		4	
Make display persistent	4		1	2
Enhance UHF or VHF frequencies	2			
Display use times		2		
Add a list of future events		1		
Add an SUA conflict probe		1		
Add brightness control		2	1	
Allow data repositioning			1	
Use different color			1	
Display off-screen				1
Display miles-in-trail				3
Persistent altitude display				1
Separate miles-in-trail button				1
Drop route lines				1

4.4. Operational Issues

A total of eight safety-related events occurred during the three days of testing. (See Table 4.) These events consisted of five operational errors, two operational deviations, and a pilot deviation. Each of these incidents was reviewed individually using Camtasia playback and voice recordings.

Table 4. Safety-related events.

Type of Error	Standalone	Integrated
Operational Errors/Deviations	4	3
Pilot Deviations		1

Conflict alert and conflict probe were not factors in the errors and deviations associated with the Standalone CIT. Controller scan, however, did seem to play a role. On two of the four Standalone errors/deviations, the controller was focused on completing other lower priority tasks or on another conflict. In each of these errors, the controller's scan was diverted from the radar display to the Standalone CIT for information as the events were developing. In addition, the operational deviations in the Standalone CIT condition occurred due to aircraft penetrating the SUAs that were displayed on the Standalone display instead of being co-located with the aircraft on the radar display.

Operational errors during scenarios where the Integrated CIT was in use were primarily attributed to controller difficulties using the automation tools. (See Figure 17.) The conflict probe and conflict alert functions failed to identify potential conflictions to the controller on three occasions. The conflict-detection functions were identical between the two CIT conditions, and yet the errors were attributed to different causes in the Standalone condition. Finally, one of the operational errors in the

Integrated CIT condition was related to the diversion of the controller's scan to other areas of the display to address other conflicting traffic.

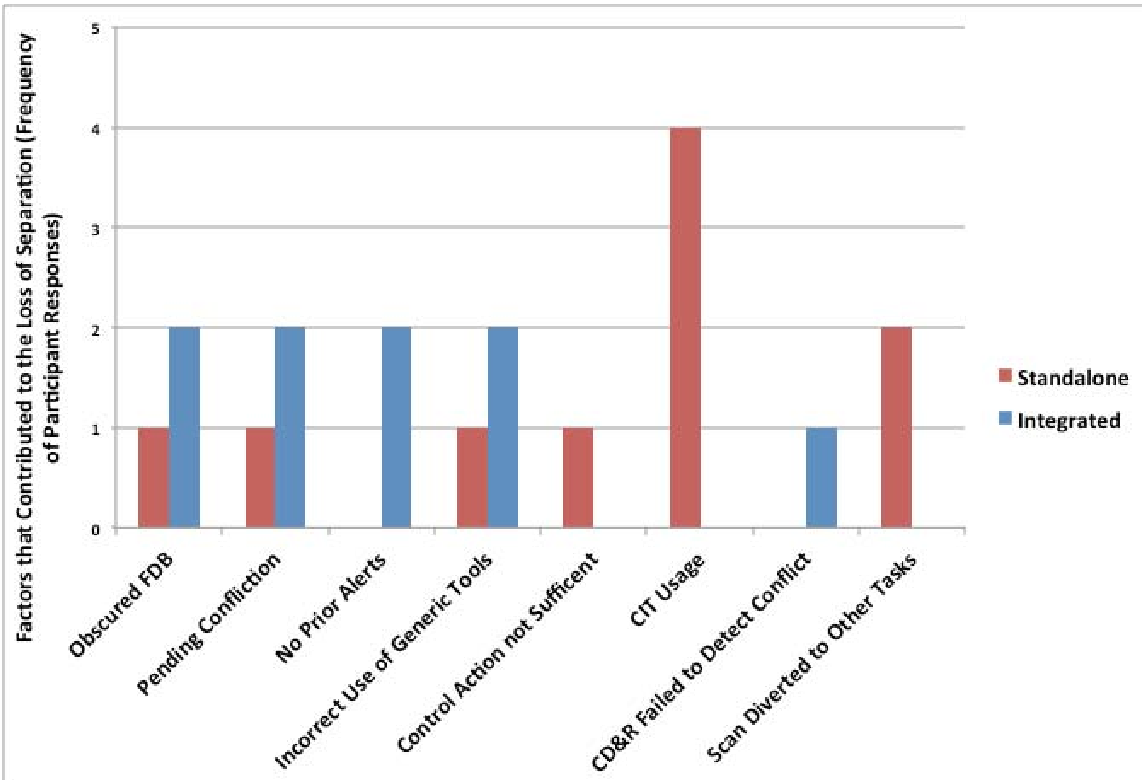

Figure 17. Contributing factors to loss of separation events. (FDB = Full datablock)

5. Discussion

5.1. Workload

This study was designed to gauge the participants' ability to control traffic approaching the MAP value for ZOA sector 30/33 using features designed to reduce the need for training. DataComm and CD&R were also provided to help manage the task load for the controllers. Nevertheless, traffic workload and complexity level, coupled with the participants' unfamiliarity with DataComm and CD&R, resulted in high overall workload assessments.

At the conclusion of day 1, participant feedback indicated that additional training on these tools was required and an hour of instruction in DataComm and CD&R in MACS was added for the following three days of testing. Nonetheless, the participants' workload assessments for the remaining days continued to be high. The high sector workload may have limited their ability to fully use the CIT. This suggests that, in research settings, proper training on advanced tools is required to ensure that controllers have the proficiency necessary to use them effectively.

5.2. Controller Preferences

The study shows that, based on subjective feedback in a controlled environment, users strongly preferred the Integrated CIT that placed the sector data on the radar screen. Use of the Standalone CIT seems to have resulted in a loss of visual attention to the main radar display. Participants tended to use keys that accessed specific information needed for managing traffic flow and communications transfers. Keys that gave general situational awareness of the sectors were used less often.

Participants normally viewed route data early in the scenario to ascertain the correct transition altitudes and did not need to access them further. Controllers were able to learn these altitudes quickly and apply the information correctly throughout the problems. Frequency information, however, needed to be accessed more often. The sector key was primarily selected to verify sector stratification.

5.3. Factors that Impacted CIT Location

Although the participants preferred having the CIT on the radar display, there is a limit on the amount of information that can be included before visual clutter becomes an issue. Good display design should be able to minimize this problem.

In this study, the results suggested that clutter was a problem. The CIT was actively turned off more often when using the Integrated CIT. The results were most prominent for the route keys, indicating that they created the most clutter. When using the Integrated CIT, route data were viewed within the sector boundaries and had an impact on the controller's traffic display.

The factors that may play a role in determining the costs and benefits of displaying CIT data are:

1. Does the CIT create display clutter such that it interferes with air traffic control tasks?
2. How often is the information needed?
3. Does the information need to be viewed in the context of the traffic (e.g., locations of the SUAs in relation to the aircraft)?
4. Should the CIT items always be on, or disappear after a period of time?

Most of the frequency and sector data were located outside the sector boundaries, with the exception of sector 30/33 and 46 data. (Sector 46 was below sector 30/33.) These data were relatively unobtrusive and located away from the area being scanned by the controller, suggesting that they did not significantly interfere with the controllers' tasks. Given that the frequency information was used most often, it seems to be a good candidate for inclusion on the radar display.

Finally, controller situational awareness of active SUAs may have been impacted using the Standalone CIT. Although SUA data were displayed on both CITs during each run, the Standalone CIT was away from the controller's scan. No memory aids existed in the controller's field of vision to alert the controller to conflicting airspace.

6. Conclusions

A human-in-the-loop evaluation was completed to study Standalone and Integrated CITs. Participants were able to access information essential to successful air traffic operations in a busy, high altitude sector. The controllers strongly preferred the Integrated version of the CIT. The primary reason for this seemed to be that it allowed them to remain focused on the traffic situation, whereas the Standalone CIT required them to move their attention away from the radar presentation for short periods.

The only detectable operational difference was that the location of the Standalone CIT might have contributed to some losses of separation. Participants accessed each CIT about equally, and the location of the data on-screen or off-screen did not inhibit their use. Although the information selected was similar for the two conditions, participants actively turned off the data on the Integrated CIT, presumably to reduce the clutter on the radarscope.

A caveat to the above results is that the high workload and complexity presented to the participants may have negatively impacted full use of the CITs. Information accessed during heavier traffic periods was limited to that deemed critical by the participant. Nevertheless, it was helpful to learn about controller use of the CIT under these conditions. Follow-up studies that explore CIT applications in a range of traffic situations would provide a fuller picture on the proper design of displays of sector information.

The data chosen for these versions of the CIT were based on the results of previous human-in-the-loop studies and from controller subject matter expert feedback. Further work in this area is needed to identify what additional CIT data should be made available to controllers. It would be ideal to build a display architecture that is scalable, meaning that as data needs arise in the NextGen vision, new items can be added and presented to the controller.

7. References

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