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Staffed NextGen Tower Human-in-the-Loop (SNT HITL 2): Camera Integration Evaluation

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16. Abstract

Objective: The purpose of this study is to investigate the effect of a Staffed NextGen Tower (SNT) environment on air traffic control (ATC) operations. The primary objective was to determine whether cameras are beneficial for SNT operations. **Background**: The SNT concept shifts from relying primarily on the out-the-window view to a model that relies more on using surveillance and cameras. There are different ways to implement the SNT concept. Two alternatives are Supplemental use (in addition to out the window display) and Contingency use (when the out the window view is unavailable). **Method**: Eight controllers ran traffic in this study with two main conditions, Supplemental and Contingency, with four off-nominal events (aircraft crosses unoccupied runway, aircraft crosses occupied runway, wheels up on approach, aborted takeoff aircraft on runway). **Results**: The controllers were able to perform their jobs effectively in both Supplemental and Contingency conditions using cameras and surveillance displays. Controllers in conditions with the camera consistently detected the "wheels up on approach" off-nominal condition. Controllers in conditions without the camera did not detect the "wheels up on approach" off-nominal condition at all. The other three off-nominal conditions were detected primarily using the Traffic Information Display System (TIDS) and alerts. The controllers rated the camera as essential in both Supplemental and Contingency conditions, although less for Supplemental than Contingency. Controllers agreed that the SNT concept would be beneficial for the National Airspace System (NAS) and for control tower operations. **Conclusion**: Results of this study show that controllers can perform their jobs effectively in both Supplemental and Contingency SNT environments and show that cameras provide a benefit to operations. **Applications**: These findings will directly influence decisions on the SNT concept implementation. Although cameras were found to be beneficial, we will still need to refine the details of camera coverage, display configuration, and control functionality. We believe that small improvements based on controller feedback from this study should lead to enhanced situational awareness for controllers and improved ATC performance.

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Executive Summary

The Staffed NextGen Tower (SNT) concept entails a shift from a current model of tower operations that relies primarily on the out-the-window (OTW) view to a model that places greater or total reliance on using surveillance for providing tower control services. By shifting from a model of control that relies on the OTW view to one that relies on surveillance displays, the Federal Aviation Administration (FAA) expects that it may be able to increase capacity at night or during periods of inclement weather when impaired visual observations might otherwise lead to delays or reduced airport access levels. Such a shift may also enable controllers to perform remote operations from a ground-level facility for contingency operations.

In the SNT Human-in-the-Loop (HITL) simulation (SNT HITL 2), we evaluated the two proposed operational implementations of the SNT concept: Supplemental SNT and Contingency SNT. In the Supplemental SNT environment, the controllers would have airport surface information displayed on an integrated surveillance display suite within the existing tower cab. The controllers would be able to use a surveillance display deemed to be operationally suitable for separation as their primary means of providing air traffic control (ATC) services. In the Contingency SNT environment, the primary display suite would be available in both the tower facility and in a ground-level SNT facility. This would provide the capability to offload tower services to a contingency facility in case of an emergency situation (e.g., a power outage, a fire in the tower, or a medical emergency).

Because controllers today rely primarily on the OTW view, we attempted to determine what role cameras might play in augmenting surveillance displays in both a Supplemental and a Contingency SNT condition. We also examined whether cameras with alerting logic would increase *controller situation awareness* of off-nominal events. To evaluate any potential benefits of cameras, we tested the Supplemental and Contingency environments both with and without the camera views.

We found that of the four planned off-nominal events in the study, the only one detected via the camera views with any consistency was when an aircraft attempted to land with its wheels up. This particular off-nominal occurred on arrivals and was detected primarily via the Picture-in-Picture (PiP) camera window. The PiP was set to track the arrivals, which meant that the aircraft with the gear up was typically the object of focus for the PiP. Although there was no alerting logic for this event, 7 out of 8 controllers detected the event when the camera was available and all of those detections were aided by the PiP camera display. No detections occurred when there was no camera.

The other off-nominals were generally detected via the Tower Information Display System (TIDS) or via the audible alerts, and not by means of the camera views. For aircraft nonconformance with taxi instructions, the controllers successfully identified the off-nominal using just the TIDS, which is an indication that the controllers did not need cameras or alerts to detect this event. However, when alerting was available, the means of detection were split between the TIDS and the alerts, indicating that the controllers did use the alerts when they were available.

The eye-movement data were all consistent with the local controllers being more likely to use the TIDS or the PiP to perform their tasks, and with the ground controllers being more likely to use the OTW to maintain their situation awareness. We also found no decrement in controller performance metrics in the Contingency SNT environment.

In general, median subjective ratings of situation awareness were higher for the TIDS than for the OTW. However, the median OTW ratings were also consistently high. These ratings indicated that the controllers believed it was necessary to have access to some type of visual of the operational environment to allow them to perform their tasks adequately.

Although the cameras and the Flight Data Manager (FDM), an electronic flight strip tool, were both rated lower than the TIDS and the OTW, especially in the Supplemental SNT condition, the ratings for the camera display and its various inset windows were positive and the ratings were even higher when there was no OTW view. The ratings were likely lower in the Supplemental SNT condition because in Supplemental SNT the windows provided the controllers with their primary view of the operational environment. Therefore, the camera views were less critical in this context for maintaining situation awareness. The ratings for the auxiliary scanning camera, the scanning camera window on the auxiliary display, were sometimes lower than for the PiP scanning camera. This is likely because when using the scanning camera on the TIDS, the PiP camera was easily accessible and the controllers did not have to look away from their primary situation display, which could have potentially resulted in a decrease in their situation awareness during busy traffic periods.

On the basis of this study and on the objective and subjective metrics, we believe that we have demonstrated the camera's importance to the SNT concept. The controllers believed that the SNT concept would be beneficial for the NAS and for tower operations. In addition, they believed that the camera was essential for implementing the SNT concept, especially in the Contingency SNT environment. We believe that the SNT concept merits further study as does the camera computer-human interface (CHI) to help us refine and expand the findings from this study. The feedback we received from the controllers regarding camera coverage, display configuration, and control functionality will guide the development of the camera CHI for future SNT HITL studies. We believe that incorporating the suggested controller improvements for the camera concept and camera CHI will be beneficial and should lead to an increase in controller situation awareness and better overall ATC performance.

1. INTRODUCTION

The Joint Planning and Development Office has outlined a plan to address the future needs of the National Airspace System (NAS) in the Next Generation Air Transportation (NextGen) concept. One component of this concept is the Staffed NextGen Tower (SNT) concept that envisions a shift from using the out-the-window (OTW) view to using surveillance as the primary means for providing tower control services. By shifting from a model of control that relies on the OTW view to one that relies on surveillance displays, we may increase capacity at night or during periods of inclement weather when impaired visual observations might otherwise lead to delays or reduced airport access levels (Nickleson, Jones, & Zimmerman, 2011). Such a shift could also enable controllers to perform remote operations from a ground-level facility for contingency operations.

1.1. Background

The Federal Aviation Administration (FAA) currently envisions two proposed SNT operational environments:

- **Implementation 1: Supplemental SNT** – In Supplemental SNT, the controllers will have airport surface information displayed on an integrated surveillance display suite within the existing tower cab. The controllers will be able to use this as their primary means of providing Air Traffic Control (ATC) services.
- **Implementation 2: Contingency SNT** – In Contingency SNT, the primary display suite would be available in both the tower facility and in a ground-level SNT facility. This would provide the capability to offload tower services to a contingency facility in case of an emergency situation (e.g., a power outage, a fire in the tower, or a medical emergency). However, the controllers will still provide primary tower services in the tower cab. The Contingency SNT configuration would serve only as a safety backup.

In this study, we explored how we might integrate cameras into the controllers' display suite and the purpose they may serve as part of the SNT concept. We believe that camera views may be useful for the controllers in a variety of situations. For example, in Supplemental SNT the controllers may use cameras to view areas with blocked lines of sight, to view critical movement areas, and to identify and track off-nominal situations. In Contingency SNT, camera images could take the place of the OTW view for a controller situated at a remote facility.

In order to maintain an acceptable level of safety when providing air traffic services in a Contingency SNT configuration, even though the surveillance system will be operationally suitable for use as their primary situation display, there may still be a need to provide tower controllers with some form of visual capability with cameras. In this configuration, the concept of operations for the cameras is to provide the controllers with some form of digital-camera surveillance to provide the visual coverage of the airport surface and some of the immediately surrounding airspace. The purpose of this camera surveillance would be to provide the controllers with an additional situation awareness tool that could help them respond more rapidly and more effectively to off-nominal events (Nene, 2011).

This study is the next step in continuing SNT research efforts that have included Quick Look studies (Hannon, 2009), Cognitive Walkthroughs (George Mason University, 2009), and Human-in-the-Loop (HITL) studies (Hannon et al., 2008; Hannon, Lee, Sheridan, & Donohoe, 2008). In the spring of 2010, the FAA conducted the SNT HITL 1 study (Nickleson et al., 2011) where tower controllers had access to an Airport Surface Detection Equipment, Model-X (ASDE-X) style display called the Tower Information Display System (TIDS) and an electronic flight strip tool called the Flight Data Manager (FDM). SNT HITL 1 examined tower controller performance during off-nominal events and provided an initial evaluation of the impact of a Phase 1 SNT environment on capacity metrics, heads-up and heads-down time, workload, and situation awareness. HITL 1.5 was a part-task activity that explored how cameras might be integrated onto SNT displays and the purpose they might serve as part of the SNT concept (Friedman-Berg, Racine, Jones, & Baptiste, 2012). The DFW 2 Field Demo tested the TIDS and FDM in the field and provided an evaluation of cameras in a field setting (FAA, 2011a, 2011b). The present study, SNT HITL 2, has been designed to provide us with a preliminary examination of the controllers' ability to identify and respond to off-nominal events both with and without cameras in both the Supplemental and Contingency SNT configurations. In SNT HITL 2, we evaluated the computer-human interface (CHI) for the SNT display systems, including the TIDS, the FDM, and the camera displays. We also evaluated the camera integration with the SNT displays, the camera integration concept, and the controller responses to off-nominal events both with and without the camera.

1.2. Purpose

This study's primary objective was to determine whether cameras were beneficial for SNT operations in either the Supplemental or Contingency environment. As a part of the SNT HITL 2, we collected user feedback to identify CHI issues related to integrating the camera views onto the SNT displays and to help us develop the concept of operations for incorporating cameras into the SNT environment.

In the SNT environment, it is possible that having a camera would increase controller situation awareness of off-nominal events. Therefore, we included off-nominal events in SNT HITL 2 to determine whether cameras are a viable mode of detection for certain types of events, such as those events that may not be adequately detected using surveillance alone. For example, if an aircraft needs to abort a takeoff or has a problem with the landing gear, the controllers may be able to use the cameras to verify the status of the situation or for increased situation awareness. The presence of a camera view may be especially useful when there is no OTW view (Nene, 2011).

2. METHOD

This study was a collaborative effort involving support personnel from the Target Generation Facility (TGF), the NextGen Integration and Evaluation Capability (NIEC), and the Massachusetts Institute of Technology Lincoln Laboratory (MIT LL). This study was conducted over a period of four weeks in June 2011 at the FAA William J. Hughes Technical Center's (WJHTC) NIEC laboratory in Atlantic City, NJ.

2.1. Controllers

Eight Dallas Fort-Worth International Airport (DFW) controllers participated in this study. Two DFW front line managers (FLMs) served as Subject Matter Experts (SMEs) during the shakedown and simulation. To limit the required training time, only controllers who had participated in past simulations or field studies participated in this study. The controllers traveled in teams of two to the WJHTC for three days of data collection.

2.2. Personnel

A Principal Investigator (PI) from the Human Factors Team – Atlantic City led the research team, which was composed of Human Factors Engineers (HFEs), ATC SMEs, system engineers, software developers, aeronautical engineers, simulation pilots, and computer scientists. The PI and HFEs designed and managed the study, developed the test procedures, and collected and analyzed the data. The engineers, computer scientists, and software developers developed and supported the simulation platform and the prototype systems. Eight simulation pilots controlled the simulated aircraft.

2.3. Facilities

2.3.1. NextGen integration and evaluation capability

The NIEC lab, which is located at the WJHTC, is a facility that allows the FAA to explore, integrate, and evaluate the NextGen concepts in a unified simulation research environment. The NIEC Tower Visualization System has a six channel, 180° field of view, OTW tower simulation capability. The OTW view is displayed on six 73-inch Mitsubishi high-definition (1080p) television screens. Based on the open source projects, Open Scene Graph and Multi-Purpose Viewer, the OTW tower simulation capability is integrated with the NIEC systems. The SNT HITL 2 simulation was based on the Common Image Generator Interface standard.

2.3.2. Target generation facility

The TGF infrastructure is capable of simulating air and ground traffic and driving terminal, en route, and developmental laboratories. The TGF enables researchers to investigate new systems and procedures without having to fly hundreds of actual aircraft. The TGF has the capability to simultaneously generate up to 600 aircraft targets from a selection of nearly 135 different aircraft types. The automation systems process and handle TGF targets as it would actual radar data.

2.3.3. TGF simulation pilot laboratory

In the TGF Simulation Pilot Laboratory, simulation pilots can pilot up to 400 simulated targets in real-time. The simulation pilots control the simulated targets by entering commands at workstations designed to control up to 15 aircraft each. An audio system connects the simulation pilots and air traffic personnel, with each simulation pilot communicating to the controllers on unique control frequencies. This enables researchers to create a realistic party-line effect on the radio channels. The TGF provides target information in radar data format, including azimuth reference information, for up to 50 simulated radars and allows researchers to emulate and test any radar-dependent ATC system.

2.4. Hardware and Software

2.4.1. Standard Terminal Automation Replacement System

The Distributed Environment for Simulation, Rapid Engineering, and Experimentation (DESIREE) platform consists of a series of interchangeable Human Machine Interfaces, which are used by Engineering Research Psychologists to develop user-interface enhancements for future inclusion in the NAS. The software runs on a PC using CentOS release 5.3 (Final).

DESIREE contains a Standard Terminal Automation Replacement System (STARS) interface, which we used to emulate the DFW's Common Automated Radar Terminal System (CARTS) system. The emulated display was presented on a 20-inch, flat-panel monitor that measured 16" by 20" with 1200 x 1600 resolution. The TGF provided DESIREE with the aircraft location and movement data, which DESIREE translated into the data tags displayed on the STARS or CARTS interface. In most simulations, controllers interact with STARS or CARTS using a keyboard and a trackball, but we did not use a keyboard or trackball in this simulation because no interaction with CARTS was required. The controllers could choose to stand or sit in a height-adjustable drafting chair while controlling traffic based on their individual preferences.

2.4.2. Tower Information Display System

The controllers used the TIDS display as their primary tactical display. The TIDS provided the controllers with a visual depiction of the airport surface and aircraft targets, and the controllers could tailor the display to present the information most pertinent for their position (see Figure 1). The TIDS interface was displayed on a 30-inch, flat-panel monitor that measured 17.9" by 27.2" with 1600 x 2560 resolution. The monitor was mounted on a Video Electronics Standards Association (VESA) articulating arm. The TIDS was designed to incorporate a variety of situation awareness tools, such as data tag information for each flight, runway hold bars, and a wake-turbulence countdown clock.

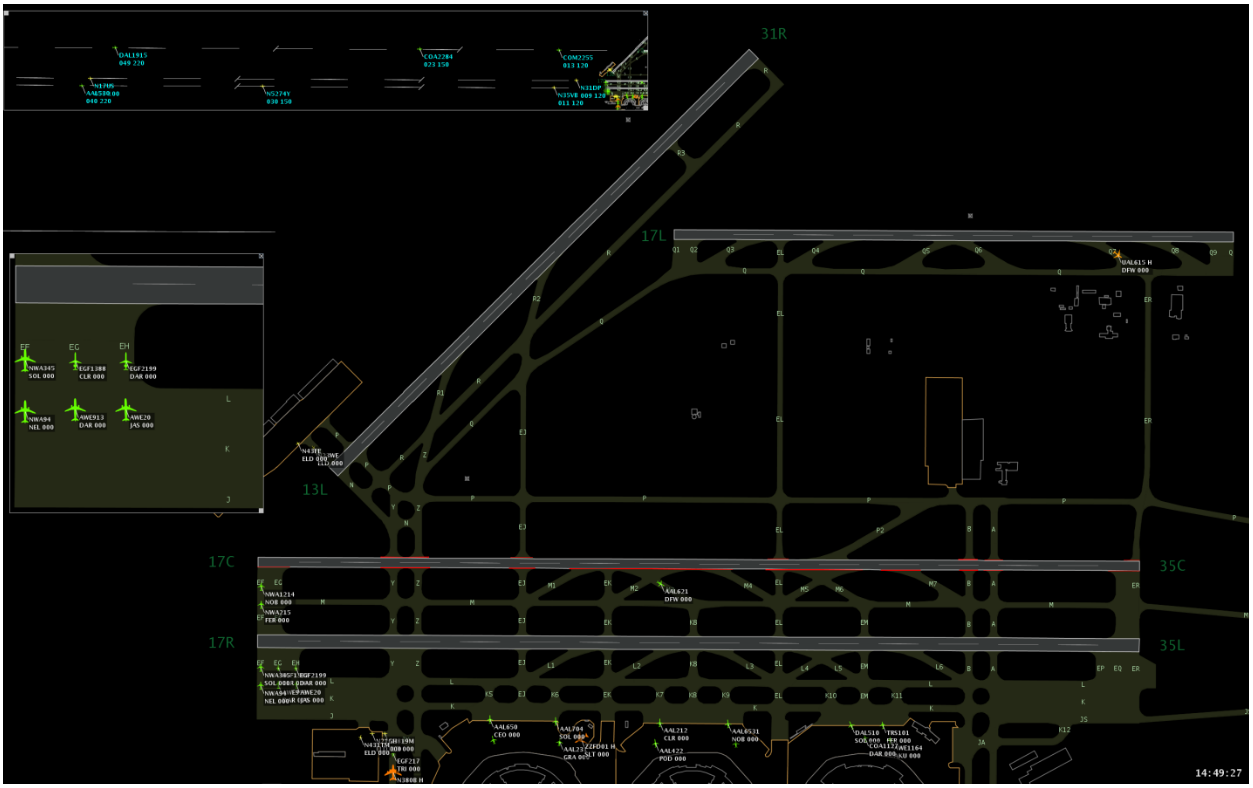

Figure 1. An example of the Tower Information Display System.

2.4.3. Terminal Flight Data Manager

In SNT HITL 2, the controllers also used the FDM tool, which provided them with an electronic display of flight information relevant for ATC and served as a tool to replace paper Flight Strips (see Figure 2). The TIDS and the FDM tool are both part of the Terminal Flight Data Manager (TFDM) suite. When a controller entered data into the FDM, this automatically updated both the FDM and the TIDS displays.

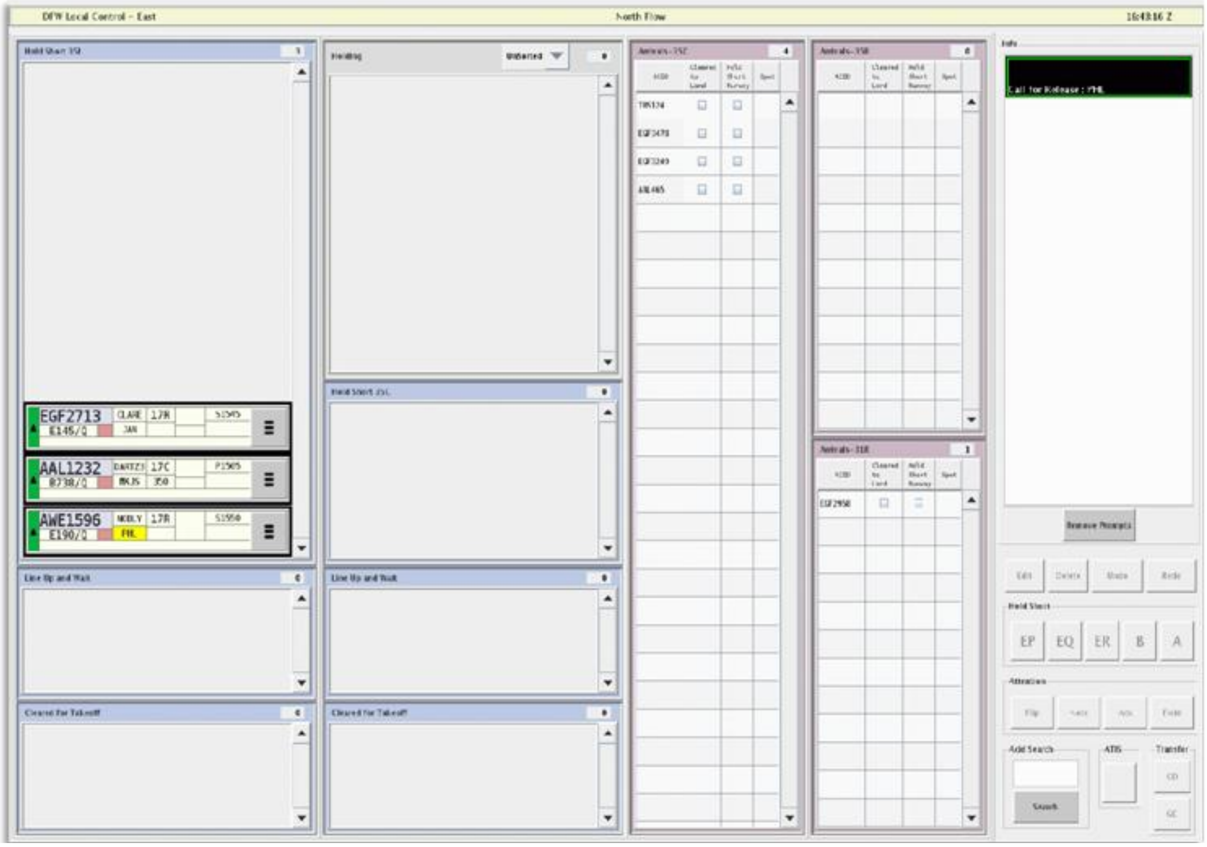

Figure 2. The Flight Data Manager graphical user interface.

As with the TIDS, the controller could configure the FDM to display the most pertinent flight information for their position. The FDM was displayed on a 24-inch, flat-panel monitor that measured 16" by 20" with 1200 x 1600 resolution. The monitor was mounted below the TIDS display using an adjustable bracket angled at 30 degrees. The FDM monitor had a touchscreen capability that allowed the controllers to drag and drop flight strips, execute aircraft clearances, and transfer the control of aircraft across positions.

2.4.4. Cohu 6960 camera

In this study, we emulated two Cohu 6960 Series cameras, one for each controller position. The Cohu 6960 Series is a two-camera system mounted on a single positioner that provides surveillance in daylight and in no light and obscured visibility conditions. One camera in the system is a day/night optical camera and one is a thermal imager. The thermal imager may be used in extreme low light conditions or environments clouded by haze, rain, smoke, or fog. The optical camera may be used for precise recognition, identification, or assessment. The optical camera provides color images in the daylight, but in low light conditions, the camera automatically switches to a monochrome mode. The camera system is designed for fast (90 deg/s) and accurate (+/- 0.1° precision) positioning and provides the user with the capability to look straight up and down and in a 360° sweep. It may be programmed with up to 64 preset positions, and up to 16 programmable zones. For SNT HITL 2, we emulated only the optical camera, not the thermal imager.

2.4.5. Fixed cameras

In addition to the two Cohu scanning cameras, we also emulated eight fixed cameras. We stitched together four of the fixed camera images to provide the controllers with a panoramic view of the airport surface on the east side of DFW airport. We positioned the other four fixed cameras to target predetermined line-of-sight areas of interest (AOIs). Two of these fixed images targeted line-of-sight AOIs relevant for the ground controller and two targeted AOIs relevant for the local controllers. All of the fixed cameras were set to an adequate level of resolution.

To generate images for each camera, TGF and MIT personnel configured and installed eleven rack-mounted Image Generators (IGs). Each emulated Cohu scanning camera required one IG, the panoramic view required four IGs, and the fixed AOI cameras required four IGs. The remaining IG served as a backup in case one of the other IGs failed.

2.4.6. Eye-tracker equipment

For SNT HITL 2, we used an Applied Science Laboratories (ASL) Mobile Eye Tetherless 30 Hz eye tracker in conjunction with the NDI Optical Tracker that, when used together, allowed for real-time, high-speed head tracking and accurate eye-position data on multiple AOIs in three-dimensional space.

2.4.7. Audio and video recording

In the simulation, we emulated three DFW frequencies.

- **Frequency 126.550** – Local Control and four Local simpilot stations
- **Frequency 121.650** – Ground Control and three Ground simpilot stations
- **Frequency 135.7** – Ground to Fire Rescue Vehicles

We used the NIEC's Interim Voice Switch Replacement (IVSR) communication panels to emulate these frequencies and to enable the communications between the controllers and the simulation pilots.

We video recorded the simulation using a color varifocal IR bullet camera (ARM Electronics C520BCDNVFIR) with a 320 x 240 resolution. We also recorded the ambient audio using short shotgun microphones (Sennheiser ME66 Series) to capture additional comments not captured by the push-to-talk (PTT) recordings.

2.5. Simulation Environment

2.5.1. Airspace

For SNT HITL 2, we used the DFW airspace and airport. We chose to use DFW for SNT HITL2 to maintain consistency with previous field demonstrations, SNT HITL 1 (Nickleson et al., 2011), and the SNT HITL 1.5 part-task camera evaluation (Friedman-Berg et al., 2012).

DFW airport is divided into an east side and west side that operate independently and maintain separate control towers. The east tower controls arrivals and departures to and from the east, and the west tower controls arrivals and departures to and from the west. The east side of DFW features four runways, three of which can be used to conduct simultaneous instrument approaches. Four one-way bridges, two eastbound and two westbound, connect the two sides of the airport. Perimeter taxiways on the east side of the airport greatly reduce the need for aircraft to cross active runways (Engelland & Ruszkowski, 2010). The airport has no intersecting runways.

For SNT HITL 2, we emulated the east side of the airport as viewed from the center tower. We chose the center tower for SNT HITL 2 and previous field demonstrations because it is not currently used and serves as a contingency facility. This allowed researchers to perform field demonstrations without having an impact on live operations. Both SNT HITL 1 (Nickleson et al., 2011) and SNT HITL 1.5 (Friedman-Berg et al., 2012) used modified DFW traffic levels and traffic flows to increase complexity. However, for the present study, SNT HITL 2, we used current DFW traffic levels and traffic flows because the procedures used did not require an increase in traffic complexity. In emulating the east side DFW traffic for SNT HITL 2 (see Figure 3), we employed the following rules and restrictions:

- The controllers were responsible for controlling traffic only on the east side of the airport.
- Some traffic taxied to and from the west side of the airport.
- The airport was in a south traffic-flow configuration.
- Aircraft landed and departed from runways 17R, 17C, and 17L.
    - All eastbound departures used runway 17R.
    - Arrivals from the east used runway 17C and 17L.

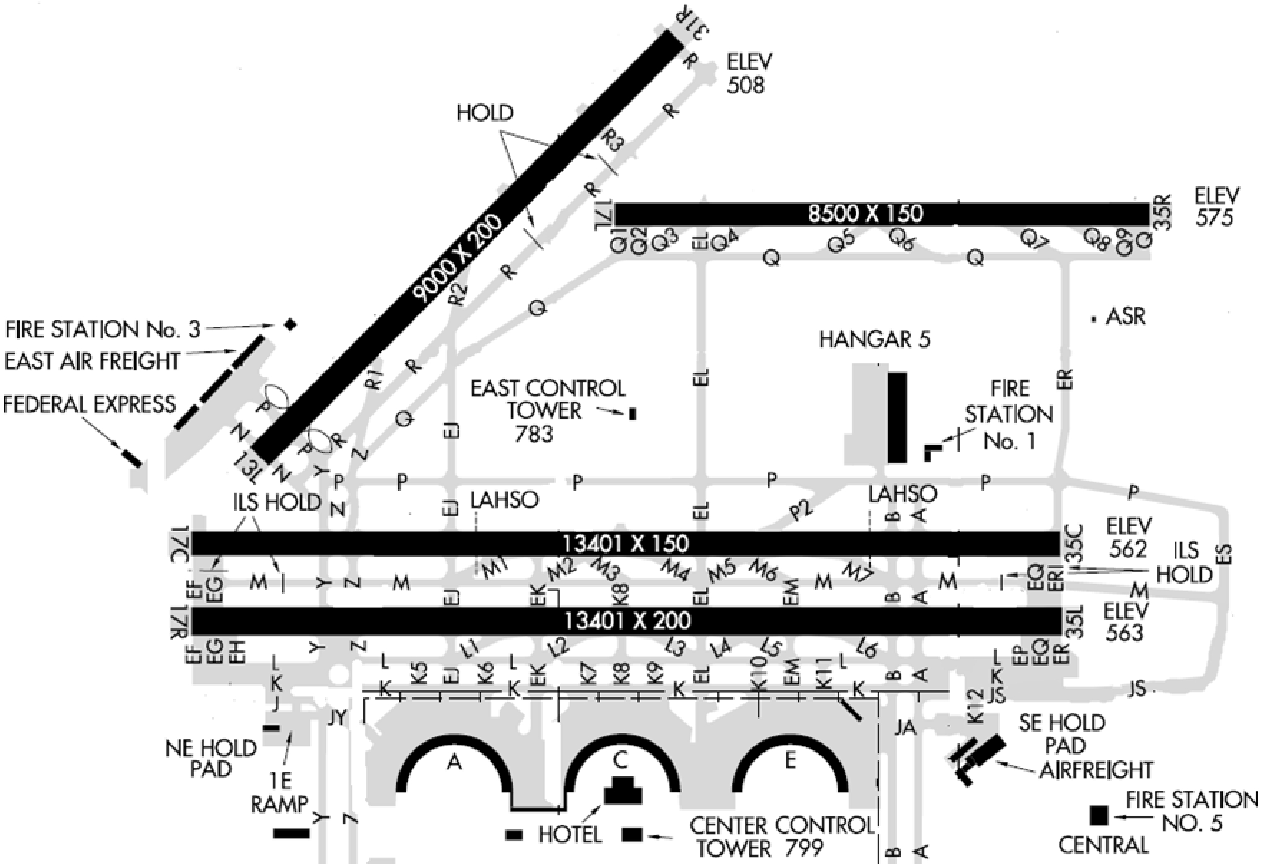

Figure 3. The DFW east side airport map.

2.5.2. Traffic scenarios

For SNT HITL 2, we created a single 40-minute traffic scenario that we used as our focal scenario. The focal scenario was a daytime scenario with an average hourly operations rate of approximately 55 aircraft per hour. We based this rate on the current rate for the east side at DFW of roughly 55 operations per hour (DFW SME, Personal Communication, April, 2011).

Using the focal scenario, we created three variations that mimicked the focal scenario in all operationally critical ways, but we altered the call-signs to make each scenario unique. We also created a 30-minute training scenario with light traffic. The scenarios were created using an MIT LL flight plan generator that models flight plans for airlines operating out of DFW. The SNT HITL 2 traffic levels were lower than those we used for SNT HITL 1 (Nickleson et al., 2011) to allow the controllers to devote adequate attention to the camera displays.

In addition to reducing traffic, we also introduced four off-nominal events during each experimental run. The controllers used Visual Flight Rules (VFR) and always had access to the TIDS and the FDM tools. The OTW view was available only during the Supplemental SNT condition, but the camera views were available during both the Supplemental and the Contingency SNT conditions (refer to the Independent Variable section for a more detailed discussion of the Supplemental and Contingency SNT conditions).

During the scenarios, we instructed the controllers to report nonconforming aircraft, unexpected aircraft maneuvers, or other unexpected situations. Observers recorded the controllers' reactions, if any, to the off-nominal events using an over-the-shoulder rating form (see Appendix A). We used the audio, user interactions, and eye-movement data to examine controller behavior and reaction time during off-nominal events.

2.5.3. Display configuration

As Figure 4 shows, the display configuration included the TIDS monitor, located on the top-center area of the controller workstation; the FDM monitor, located on the bottom-center area of the controller workstation; and the camera monitor, located to the right of the TIDS and FDM monitors.

Figure 4. Display configuration for the SNT HITL 2 simulation included the (1) Out-the-Window view, (2) Tower Information Display System, (3) Remote ARTS Color Display, (4) Camera Monitor, and (5) Flight Data Manager.

The top half of the camera display monitor contained a panoramic airport view (see Figure 5). The panoramic view was always present—it could not be minimized by the controllers—and always depicted the same view of the runways. The bottom half of the monitor was divided in two, and each half contained a separate camera inset window.

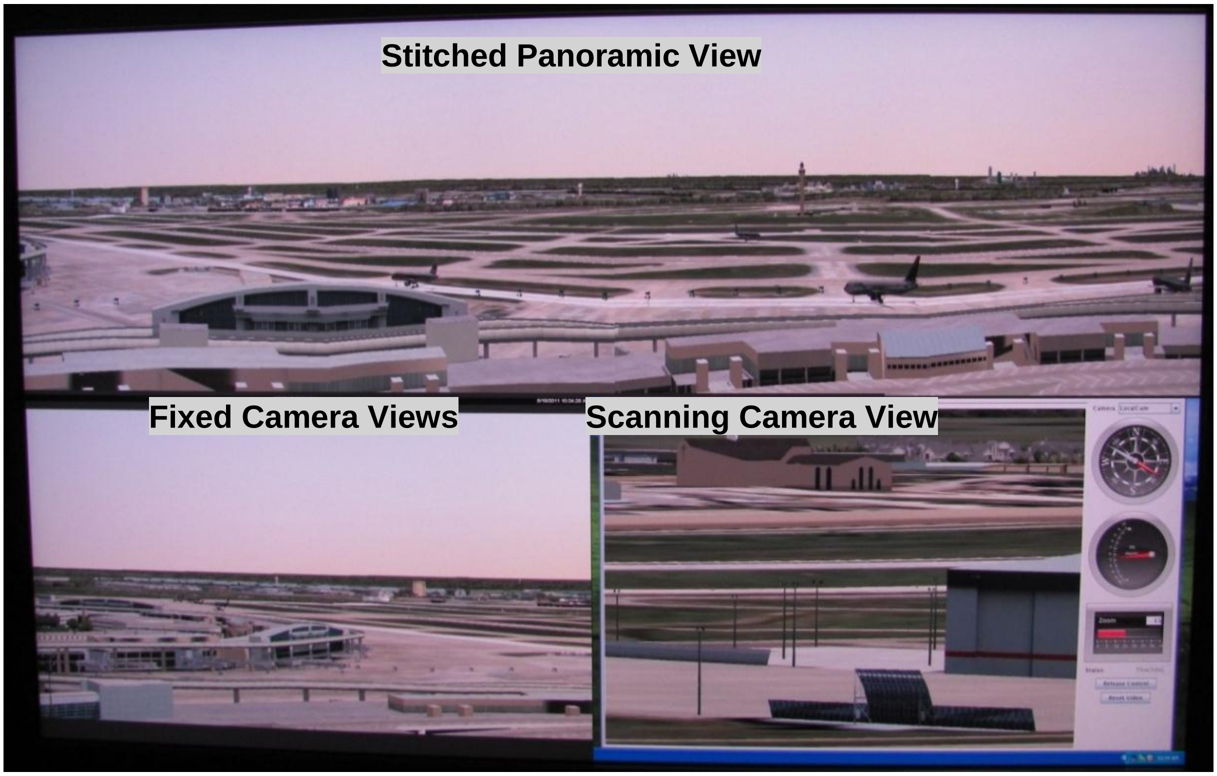

Figure 5. Camera monitor configuration for SNT HITL 2.

The right-inset window contained the scanning camera view. The alert logic helped drive the scanning camera. The scanning camera automatically tracked aircraft arrivals and also responded to alerts or off-nominal events by zooming to the aircraft involved in that event. When the scanning camera was not responding to off-nominal events, the controllers could release the automatic tracking of arrivals and instead use it to view controller-selected locations or aircraft by right-clicking the desired aircraft or location on the TIDS display.

The left-inset window contained a fixed view of one of four preselected areas. The preselected areas depicted problematic, operational areas (such as a threshold line or limited-view runway) or depicted nonoperational areas (such as blocked spots or alleyways). We chose the four fixed-camera locations based on current line-of-sight issues for the center tower at DFW. On the east side of the airport, recently built train terminals and other structures block the center tower view of ramp control spots, both at midfield and the north end of the airport. Airline terminal expansions have partially blocked the view of both the north and south bridges. The center tower also does not provide controllers with an adequate view of some runway thresholds. This is especially true for the thresholds for runways 17L and 13L. The OTW simulator view only exacerbated these problems.

In the simulation, two of the preselected viewing areas targeted known problematic areas for the ground controller and two targeted known problematic areas for the local controller. Controllers could display these preset viewing areas to help compensate for some of the known line-of-sight issues in the center tower (see Appendix B). The two areas selected for the ground controllers were (1) the spots in front of Terminal C and (2) the North Bridge and the Northeast Hold Pad. The two areas selected for the local controller were (1) the runway thresholds for runway 17R and 17C and (2) the runway threshold for runway 17L.

Although the fixed camera views targeted problem areas for a specific position, both the local and ground controllers could toggle between all four fixed camera views by moving the mouse cursor to the fixed camera inset window, clicking on the window (to gain focus), and then using the keyboard to select the desired camera location. Each camera location was assigned to a number key from 1 to 4. For the local controller, the two local control AOIs were assigned to keys 1 and 2 and the two ground control AOIs were assigned to keys 3 and 4. For the ground controllers, the ground control AOIs were assigned to keys 1 and 2 and the local control AOIs were assigned to keys 3 and 4.

2.6. Procedures

2.6.1. Briefing

At the start of the simulation, the controllers received an in-briefing and were instructed on the use of the TIDS, FDM, camera displays, Standard Operating Procedures (SOPs), Letters of Agreement (LOAs), and Memoranda of Understanding (MOUs). Researchers informed the controllers that the purpose of SNT HITL 2 was to investigate potential uses for camera technology in an ATC tower environment in both Supplemental and Contingency SNT configurations. Researchers also briefed the controllers on the camera integration concept and explained the camera procedures being used in this study.

Researchers and SMEs briefed the controllers on the SNT HITL environment, the type of data being collected, and the daily schedule (see Table 1). After the initial briefing, the controllers completed an Informed Consent Form (see Appendix C) and a Background Questionnaire online, using the Widgix Software's SurveyGizmo tool (www.surveygizmo.com; see Appendix D).

Table 1. Daily Schedule

Time	Day 1	Time	Day 2	Time	Day 3
8:30	In Briefing	8:30	Run 3	8:30	Buffer Run
9:30	Training Run 1	9:10	Post-Run Questionnaire	9:10	Post-Run Questionnaires
10:05	Break	9:25	Break	9:25	Break
10:20	Training Run 2	9:40	Run 4	9:40	Buffer Run
10:50	Training Run 3	10:30	Post-Run Questionnaire	10:30	Post-Run Questionnaires
11:25	Break	10:50	Run 5	10:50	Post-Experiment Questionnaires
11:40	Training Run 4	11:30	Post-Run Questionnaires	11:30	Lunch
12:15	Lunch	11:45	Lunch	1:00	Part-Task Run 1
1:30	Run 1	1:00	Run 6	1:30	Part-Task Run 2
2:10	Post-Run Questionnaires	1:40	Post-Run Questionnaires	2:00	Break
2:25	Break	2:00	Run 7	2:15	Part-Task Run 3
2:40	Run 2	2:40	Post-Run Questionnaires	2:45	Part-Task Run 4
3:30	Post-Run Questionnaires	2:50	Break	3:15	Debrief
4:15	Debrief	3:00	Run 8		
		3:40	Post-Run Questionnaires		
		4:00	Debrief		

2.6.2. Training

All controllers participated in four 20-minute training runs. During training, the controllers had the opportunity to interact with the systems and ask questions about the experiment. At this time, we demonstrated the controls for the TIDS, the FDM, and the cameras. We also provided the controllers with *cheat* sheets to help them remember important control commands (see Appendix E and Appendix F). Each controller had an opportunity to practice with the systems while staffing both the ground and the local control positions. They also had the opportunity to use the cameras until they felt comfortable enough to proceed to the data collection runs.

2.6.3. Data collection runs

Following the training, the controllers began the eight data collection runs. After each run, the controllers filled out a Post-Run Questionnaire (see Appendix G). If time permitted at the end of each day, the research team held a debriefing session to gather additional feedback from all of the controllers. All controllers filled out a Post-Evaluation Questionnaire (see Appendix H) and a Simulation Realism Questionnaire (see Appendix I) at the end of the study.

On the basis of the counterbalancing assignments shown in Table 2, one controller in each pair of controllers was assigned to begin Run 1 in either the local (L) or ground (G) position. Each controller had the opportunity to work both the local and the ground positions in the Supplemental SNT condition without the camera capability (1), the Supplemental SNT condition with the camera capability (2), the Contingency SNT condition without the camera capability (3), and the Contingency SNT condition with the camera capability (4). Before each data collection run, an SME conducted an in-briefing analogous to the position relief briefing that controllers would receive in an operational setting. The HFEs and SMEs served as over-the-shoulder observers during the data collection runs.

Table 2. Counterbalancing Assignments

Group	Controller Number	Run 1	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7	Run 8
1	1	G1	G2	G3	G4	L1	L2	L3	L4
	2	L1	L2	L3	L4	G1	G2	G3	G4
2	3	G2	G4	G1	G3	L2	L4	L1	L3
	4	L2	L4	L1	L3	G2	G4	G1	G3
3	5	G3	G1	G4	G2	L3	L1	L4	L2
	6	L3	L1	L4	L2	G3	G1	G4	G2
4	7	G4	G3	G2	G1	L4	L3	L2	L1
	8	L4	L3	L2	L1	G4	G3	G2	G1

Note. G = Ground, L = Local, 1 = Supplemental/no camera, 2 = Supplemental/camera, 3 = Contingency/no camera, 4 = Contingency/camera.

2.7. Experimental Design

2.7.1. Independent variables

This study evaluated two different aspects of the SNT environment, the Supplemental and the Contingency SNT environment. In the Supplemental SNT environment, we emulated operations within the tower cab with the OTW view available. The controllers were instructed that the TIDS and FDM were operationally suitable for separation in both environments.

The cameras were available for half the scenarios in the Supplemental SNT environment and half the scenarios in the Contingency SNT environment. In the Contingency SNT environment, we emulated remote operations from a ground facility with no OTW view available (see Table 3).

Table 3. Scenario Condition Matrix

	No Camera	Camera
Supplemental SNT (OTW)	1	2
Contingency SNT (No OTW)	3	4

The part-task study results indicated that controller detection of off-nominal events is difficult via the camera views because the controllers' field of view is limited to what is available on the camera monitors. In essence, the scanning cameras do not know where to look when such events take place. We also theorized that in the event of an off-nominal event, controllers would not have time to manipulate the cameras to view the area. Therefore, in addition to current, alerting logic, we implemented intelligent logic for some of the off-nominal events to aid the controller in detecting the off-nominal events. This intelligent logic was developed by MIT LL to automatically direct the scanning camera to view any aircraft in alert status. We hypothesized that the alerting capability on the TIDS would support the controllers in using the cameras to more effectively detect and respond to off-nominal events.

2.7.2. Off-nominal events

We scripted four off-nominal events (see Table 4) that were included in every scenario. The scenarios were divided into four equal segments: one for each off-nominal. The order of inclusion of the off-nominals in the scenario segments was counterbalanced across both participants and groups. Because we selected the off-nominals to be low-impact, we were able to include all of them in every run. The criteria we used for the selection of off-nominal events include the following: events that would be captured by the alerting logic, such as aircraft crossing an active runway; events that would require visual verification, such as "gear up/gear down"; and events that had an adequate potential for controller observation via the camera view, such as those off-nominals with available alerting logic.

Table 4. List of Off-Nominal Events

Events	Variations	Which camera might be used for detection	Camera Alert Logic	Comments/ Notes
1. Aircraft crosses runway (without clearance)	Active/ Occupied Runway	Scanning Camera	Yes	Events 1 and 2 give us the opportunity to directly compare an alerted vs. non-alerted off-nominal.
2. Aircraft crosses runway (without clearance)	Active/ Nonoccupied Runway	Fixed Camera Inset 1 or Panoramic	No	Note that for Event 1, the alert logic is not linked to the lack of a clearance but is, instead, triggered by the aircraft crossing the active runway.
3. Aircraft on Approach (with Gear Up)	None	Fixed Camera Inset 1 Or Scanning	No	Gears descend upon controller-issued instructions, or when the aircraft is 100 ft above the ground.
4. Aircraft stops on runway (aborted t/o)	None	Scanning Camera	Yes	Operationally useful time on runway parameter, < 25s.

All scenarios contained the four scripted off-nominal events. When feasible, the researchers recorded what time the controllers observed or reported any off-nominal events. The controllers were instructed to react to any nonconforming aircraft and to tailor their responses to the SNT environment. In the Supplemental SNT conditions, the controller instructions were to use the camera images to supplement their OTW view, whereas in the Contingency SNT condition the instructions were to incorporate the camera monitor into their normal scan.

2.8. Exploratory Runs

We included four exploratory runs on the last day to evaluate camera use during a high-impact, off-nominal event, such as a reported hydraulic failure. These runs were 20 minutes and were more limited in terms of data collection. We presented the high-impact, off-nominal event in both the Contingency and Supplemental SNT conditions in both the camera and no camera configurations to explore differences in camera use during this event.

For this event, we emulated a situation where there was an aircraft on approach for 17C with a pilot-reported hydraulic failure. The controllers implemented an SOP emergency procedure (see Appendix J). Confederates working as members of the research team served as the tower supervisor to facilitate communications with the TRACON and with the Department of Public Safety (DPS) emergency response crews. The local controller informed the supervisor of the incident after its initiation and communicated with the Fire Station Emergency crews as required. It was also the local controllers' responsibility to ensure that any aircraft on approach to the affected runway initiated a go-around.

After the affected aircraft landed, the local controllers communicated with the fire trucks involved in responding to the off-nominal. Although actual DFW DPS procedures may dispatch as many as 20 fire trucks, we deployed only six fire trucks and SUVs from Fire Station No. 1. These vehicles traveled along taxiway Papa to ensure unimpeded vehicle movement on the airport surface. We did not emulate an evacuation of passengers. After the emergency aircraft landed, the controller closed runway 17C while the emergency vehicles proceeded to the aircraft, and then escorted it off the runway. The scenario ended after the emergency vehicles completed a runway inspection and the supervisor cleared operations to resume on runway 17C.

3. RESULTS

3.1. Data Collection and Analysis

The data collected in this experiment included subjective feedback on perceived tool efficiency, perceived tool effectiveness, and the user interface design, collected from post-run questionnaires and post-evaluation questionnaires (see Appendix K for the raw questionnaire data), along with more objective data types (see Table 5). The objective data included workload as measured by eye-movement metrics, event detection, heads-up and heads-down time, PTT data, aircraft throughput data, and user interaction data. In addition, we measured situation awareness and workload using both questionnaires and eye-movement data.

Table 5. Types of Data Collected

Data	Instrument	Frequency	Source
Perceived Tool Efficiency	Post-Run Questionnaires Post-Evaluation Questionnaires	After Every Run After All Runs	On-line Survey On-line Survey
Perceived Tool Effectiveness	Post-Run Questionnaires Post-Evaluation Questionnaires	After Every Run After All Runs	On-line Survey On-line Survey
User Interface Evaluation	Post-Run Questionnaires Post-Evaluation Questionnaires	After Every Run After All Runs	On-line Survey On-line Survey
Situation Awareness	Post-Run Questionnaires Post-Evaluation Questionnaires	After Every Run After All Runs	On-line Survey On-line Survey
Workload	Pupil Diameter, Blink Duration, Saccade Distance	Continuous	Eye Tracker
Event Detection	SME/Observer	Each Occurrence	Over-the-Shoulder Form
Heads up/down	% Fixation on Displays vs. % OTW	Continuous	Eye Tracker
Communications	PTT	Number and Duration of Communications (min, max, average)	NIEC Comm Data
Throughput		Total Number of Arrivals/Departures	TGF Data Reduction and Analysis Tool (DRAT)

The data were analyzed using metrics appropriate for a repeated measures experimental design. We report point estimates and effect sizes for all reported statistics. For our main comparisons, we evaluated performance, throughput, eye movement metrics, camera usage, and communications in the Supplemental and Contingency conditions, both with and without cameras. We compared how camera usage patterns differed for the ground and local positions across the different conditions.

3.2. Background Data

Eight male DFW controllers participated in this study. The controllers' average age was 44 years, and they had an average of 19 years controlling traffic in an ATC tower (see Figure 6). All of the controllers had prior experience with SNT and were familiar with both the concept and display suite. In some cases, the controllers had participated in more than one study effort. All but two of the controllers wore corrective lenses or contacts.

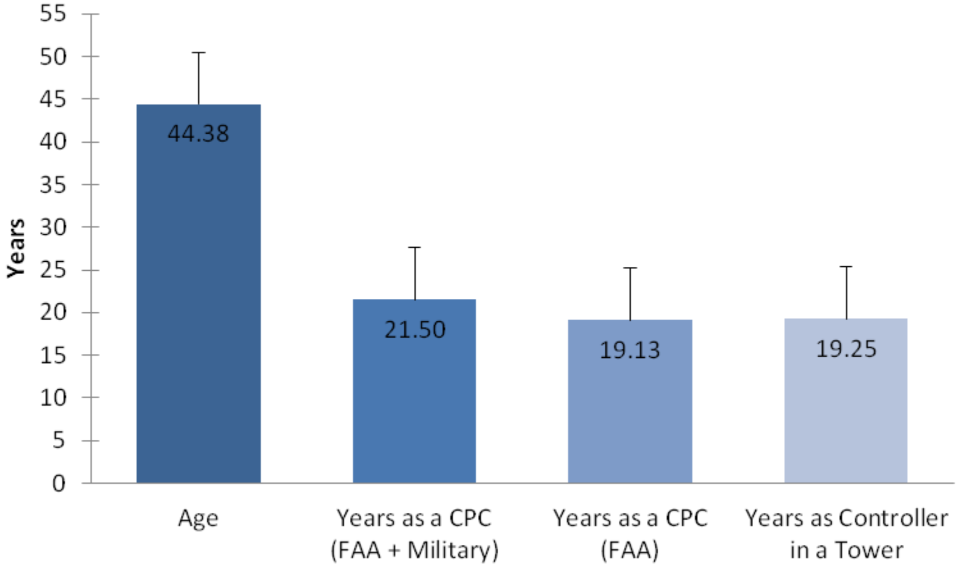

Figure 6. Controller background data.

3.3. Objective Experimental Data

3.3.1. Off-nominal detection data

The 40-minute scenarios were divided into four 10-minute segments. One off-nominal event was randomly assigned to each segment and was initiated by the simulation pilots (simpilots). To the extent possible, the simpilots attempted to script the off-nominal event so that they occurred in the middle of the 10-minute segment to create separation between each off-nominal. There were some instances when the simpilots were unable to find a target of opportunity within a particular segment. In these instances, either two events were initiated in the next segment or no event was executed. Data related to the detection of off nominal events were collected via over-the-shoulder observation and eye-tracker equipment.

By design, some of the off-nominal events had the potential to generate an alert while others did not. Also, because there was no OTW view or camera view in the Contingency/No camera condition, the controllers had no means by which to detect the gear up off-nominal in that condition.

Depending upon the experimental condition, the controllers could detect the off-nominal events via the following means: OTW, panoramic camera, fixed camera, scanning camera, scanning Picture-in-Picture (PiP), TIDS, FDM, or by an alert. It was also possible for the off-nominal to be unobserved. In this study, the primary means of detection fell mainly into the following four categories: unobserved, TIDS, PiP, or cued by alert.

For the gear up off-nominal, the event detection method appeared to be correlated with the availability of cameras. In the conditions where the controllers had access to the camera, the gear up off-nominal was detected primarily via the PiP view, but in the Supplemental SNT condition where the controllers had access to the OTW view only, they did not detect the gear up off-nominal at all (see Figure 7). This difference in detection patterns across conditions was significant, $\chi^2(2) = 16.8$, $p < .001$. There was no alerting logic for this event and it appears that the controllers had difficulty detecting this event via the OTW when there was no camera available. Although it was possible that the inability to detect the gear up off-nominal may have been due to the screen resolution of the OTW view and the non-use of binoculars in the experiment, we do not believe this to be the case as there was a similar finding in the DFW Field Demonstration 2 (FAA, 2011b). Note that this condition was not included in the analysis because the event was undetectable in the Contingency SNT condition with no camera.

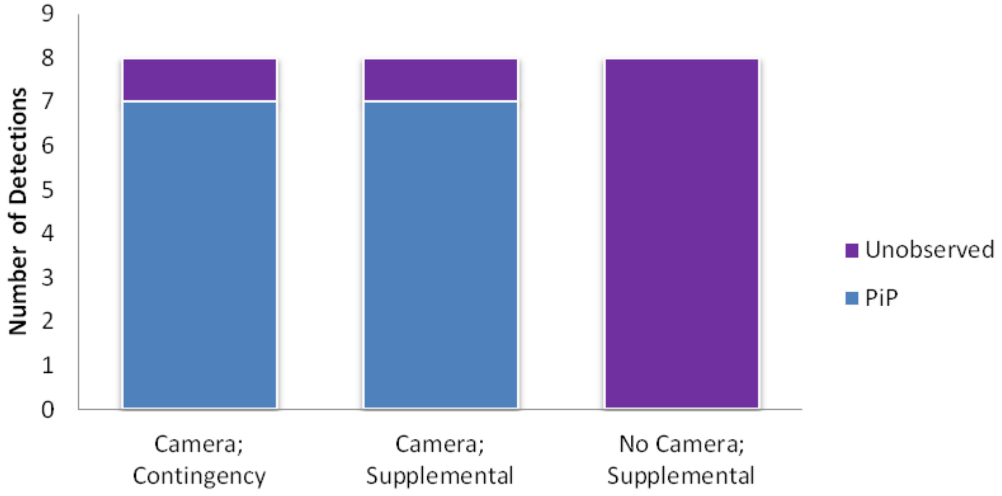

Figure 7. Means of off-nominal detection for a “gear up” event.

For the detection of the aircraft crossing an unoccupied runway off-nominal, there was no alerting logic and this off-nominal was primarily detected via the TIDS. The controllers typically noticed this event when the aircraft would deviate from its taxi instructions to take the perimeter route (see Figure 8). There was no significant difference in the primary means of detection for the different conditions.

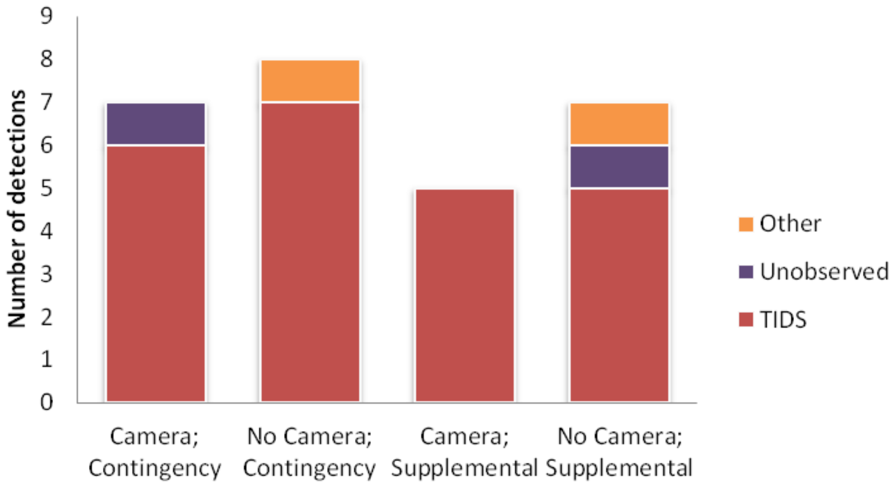

Figure 8. Means of off-nominal detection for aircraft crossing an unoccupied runway.

When the aircraft crossed an occupied runway, there was an audible alert. Therefore, the controllers sometimes detected the aircraft crossing an occupied runway off-nominal via the TIDS and sometimes via the alert (see Figure 9). However, the pattern for the means of detection was not significantly different for the different conditions.

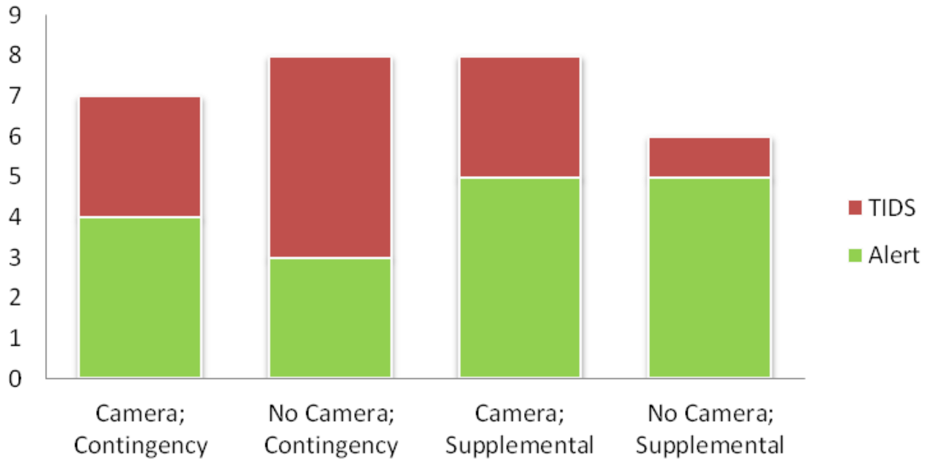

Figure 9. Means of off-nominal detection for aircraft crossing an occupied runway.

When the aircraft stopped on the runway, there was a corresponding audible alert; therefore, the controllers sometimes detected the aircraft stopped on the runway off-nominal via the TIDS, sometimes via the alert, and sometimes via the PiP (see Figure 10). There was a trend of more detections via the alerts in the Supplemental SNT condition with no camera. However, the pattern for the means of detection was not significantly different for the different conditions.

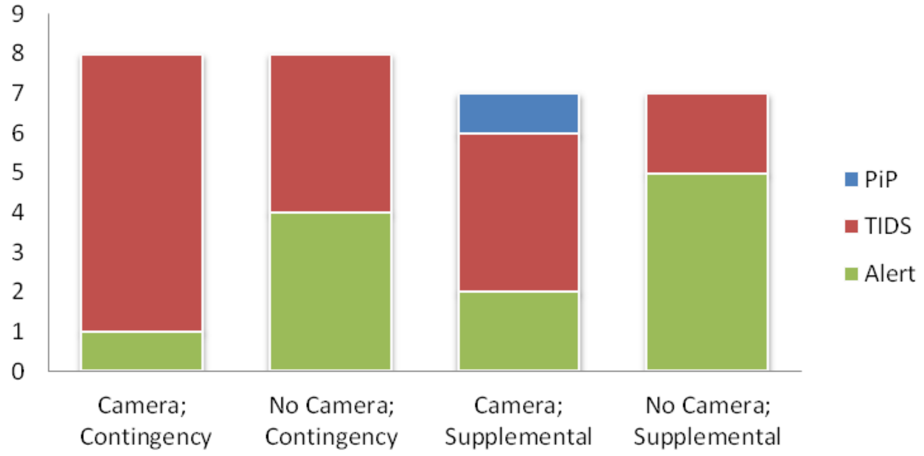

Figure 10. Means of off-nominal detection for aircraft stopped on the runway.

3.3.2. PTT data

We analyzed the PTT data to determine whether there were any differences in the average number or average duration of communications in any of the conditions. Also, because the number and duration of communications can vary by controller position, we analyzed this data by position to determine whether there were any differences across conditions for each position. The overall PTT data indicated that there was no significant difference in the average communication duration in the different conditions (see Figure 11).

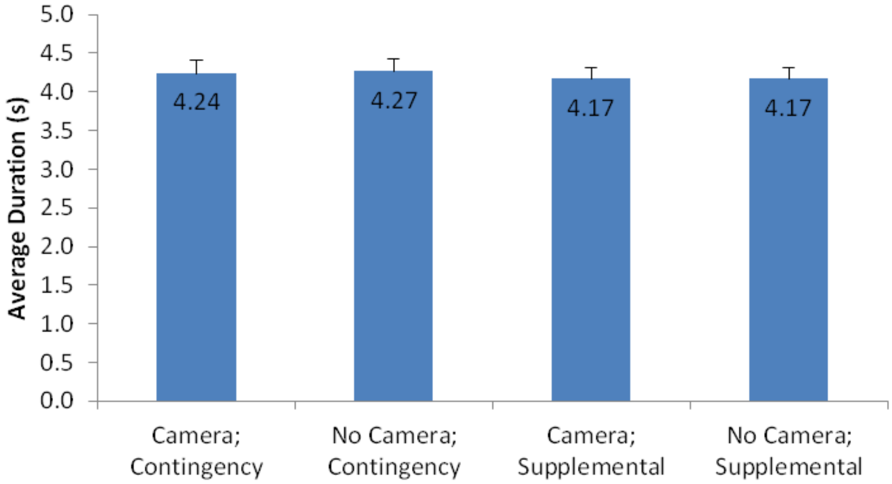

Figure 11. Average duration of PTT communication by condition.

However, when looking at the PTT durations by position, there were some interesting trends. Although not significant, the average PTT duration for the ground controllers were marginally longer in the Contingency SNT condition than in the Supplemental SNT condition, *F*(1, 7) = 4.39, $p = .07$, $\eta_p^2 = .39$ (see Figure 12). There were no significant differences based on the SNT conditions (Contingency vs. Supplemental) for the local controller and no effect of camera use on PTT duration for either the local or ground controllers.

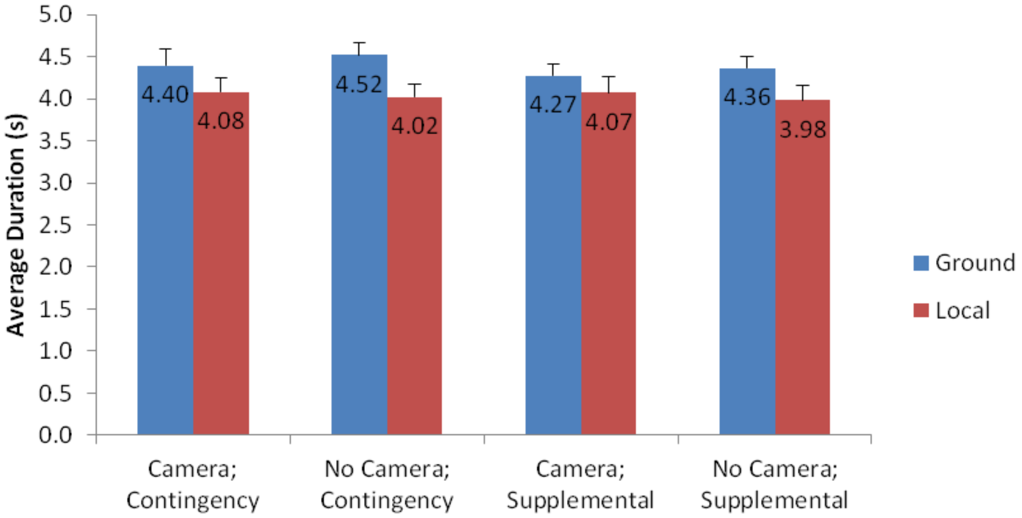

Figure 12. Average duration of PTT communications by condition and position.

We also analyzed the number of PTT communications to see whether there was an effect of camera or SNT condition on the frequency of controller communications. The overall PTT data indicated that there were no significant differences in the average number of communications based on the SNT condition or the availability of the camera (see Figure 13).

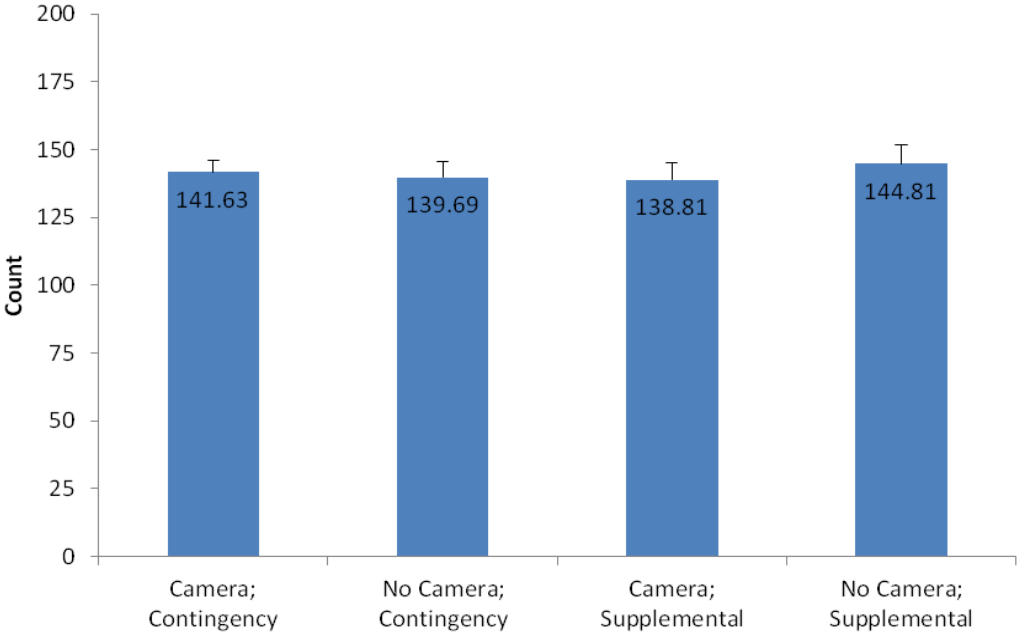

Figure 13. Average number of PTT communications by condition.

We analyzed the average number of PTT communications by position (see Figure 14). For the ground and local positions, there were no differences in the number of communications based on the SNT condition or the availability of the camera. For the ground position, there was also no interaction between the two factors. However, for the local position, there was a significant interaction between the SNT condition and the availability of the camera, $F(1, 7) = 6.15$, $p = .04$, $\eta_p^2 = .47$. When the controllers had access to the cameras, communications were longer in the Contingency SNT condition, but when there were no cameras, communications were longer in the Supplemental SNT condition.

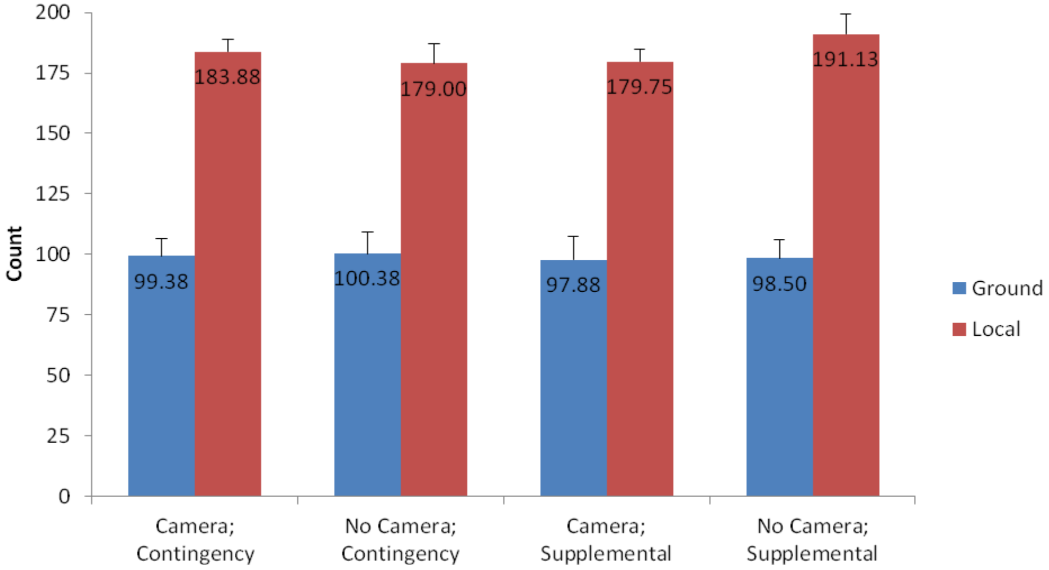

Figure 14. Average number of PTT communications by condition and position.

3.3.3. Ground-based performance data

We analyzed ground-based performance metrics to evaluate whether there were any effects of the experimental conditions on aircraft throughput. Each pair of controllers was counted as a subject twice—once when participant A worked the ground position and participant B worked the local position, and once when participant A worked the local position and participant B worked the ground position. Because the data were analyzed for pairs of controllers, it was not possible to perform an analysis by position. Looking at throughput data, there were no significant differences in the number of arrivals based on the SNT condition or the availability of the camera, and no significant interactions (see Figure 15). For the distance between arrivals (see Figure 16), the average number of departures (see Figure 17), the time between departures (see Figure 18), the proportion of total potential arrivals to land (see Figure 19), and the proportion of departures to take off (see Figure 20). There were also no significant differences between the conditions. However, it is important to note that due to experimental constraints, the number of potential arrivals and departures is fixed across conditions. Therefore, these metrics are not typically impacted in a significant manner by controller-initiated actions even though we might expect more of an impact on distance and time metrics.

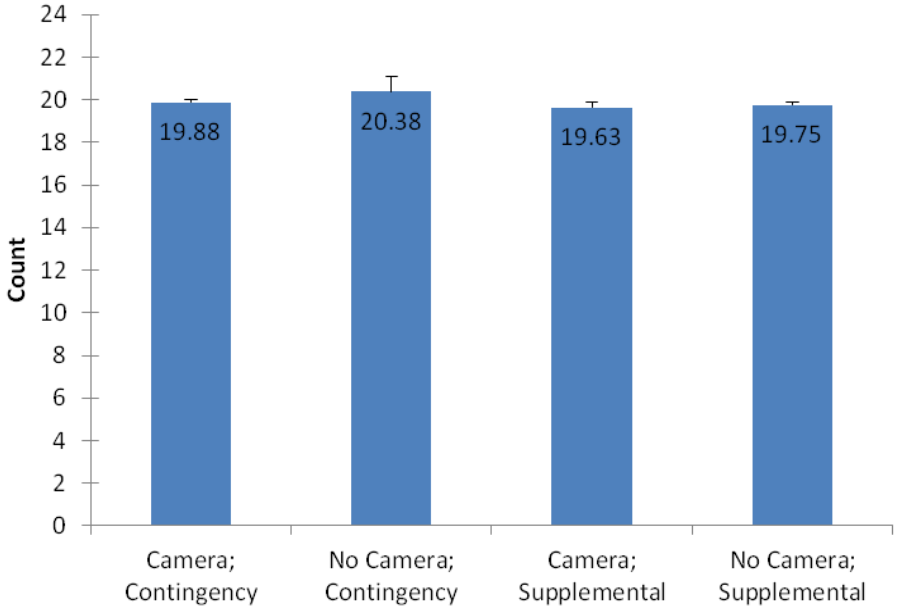

Figure 15. Average number of arrivals by condition.

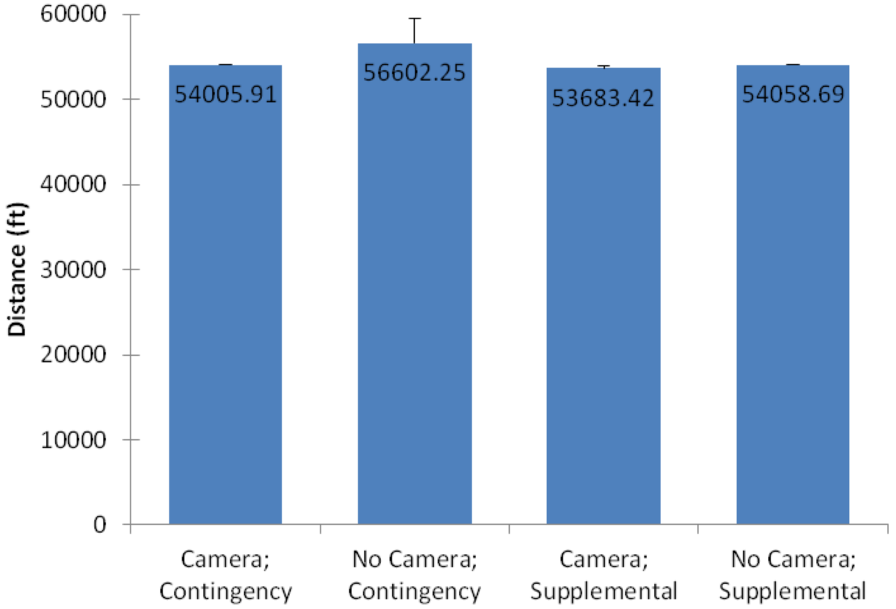

Figure 16. Average distance (in feet) between arrivals by condition.

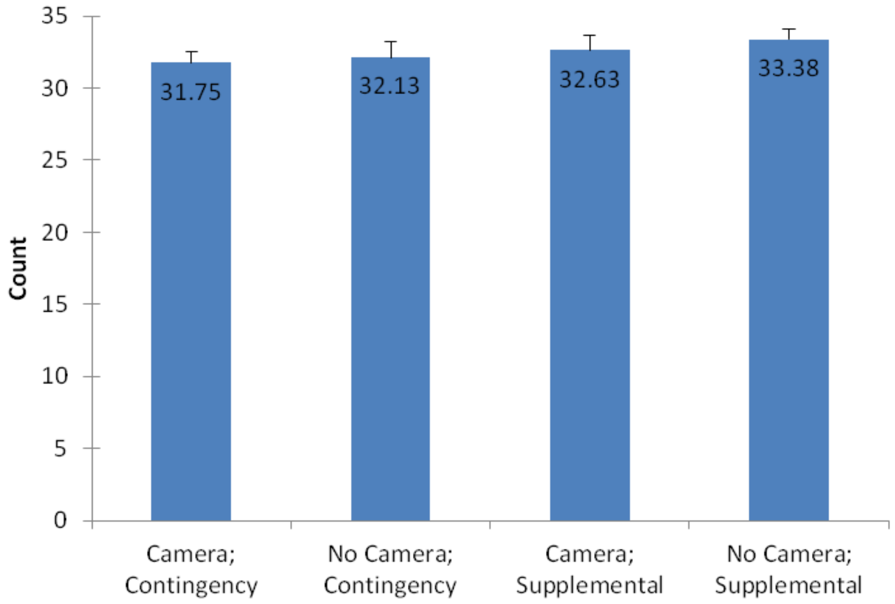

Figure 17. Average number of departures by condition.

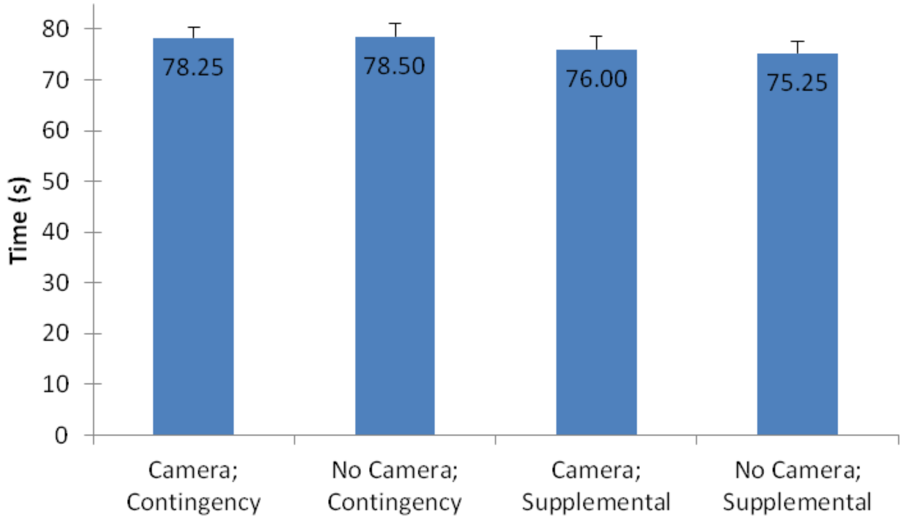

Figure 18. Average time (in seconds) between departures by condition.

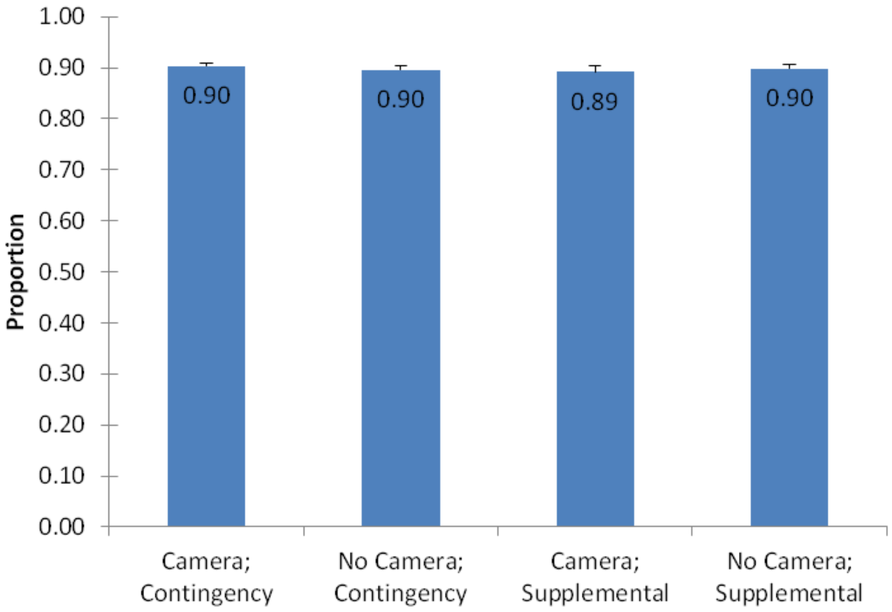

Figure 19. Average proportion of total potential arrivals.

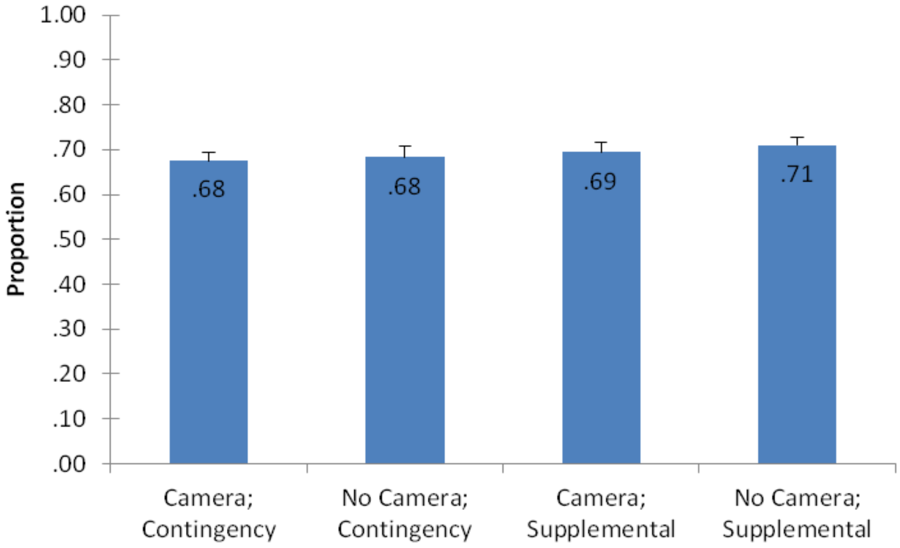

Figure 20. Average proportion of total potential departures.

For the average distance between departures (see Figure 21), there was no main effect of SNT condition or the camera, but there was a significant interaction between the two factors, $F(1, 7) = 6.29$, $p = .04$, $\eta_p^2 = .47$. When controllers had access to cameras, the distance between departures was greater in the Supplemental SNT condition, but when they had no cameras, the distance between departures was greater in the Contingency SNT condition.

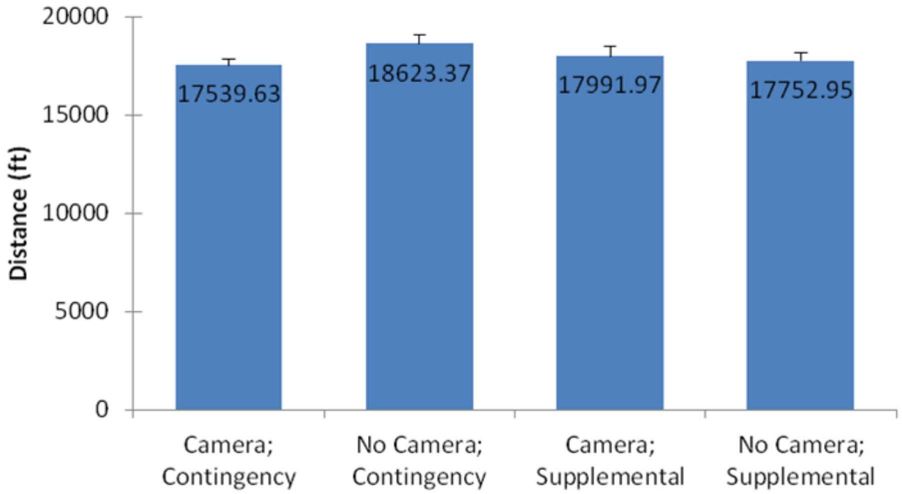

Figure 21. Means Average distance (in feet) between departures by condition.

3.3.4. Command data

We analyzed the command data to see whether the control style varied across conditions. There were no significant differences in control style for the average number of runway crossings (see Figure 22), the average number of altitude change commands (see Figure 23), the average number of frequency change commands (see Figure 24), the total number of missed approach commands (see Figure 25), the average number of resume taxi commands (see Figure 26), the average number of speed commands (see Figure 27), the average number of takeoff commands (see Figure 28), and the average number of line up and wait commands (see Figure 29) regardless of SNT condition and the availability of camera images. Across the entire simulation, there was only one reroute and no runway change commands so these were not analyzed.

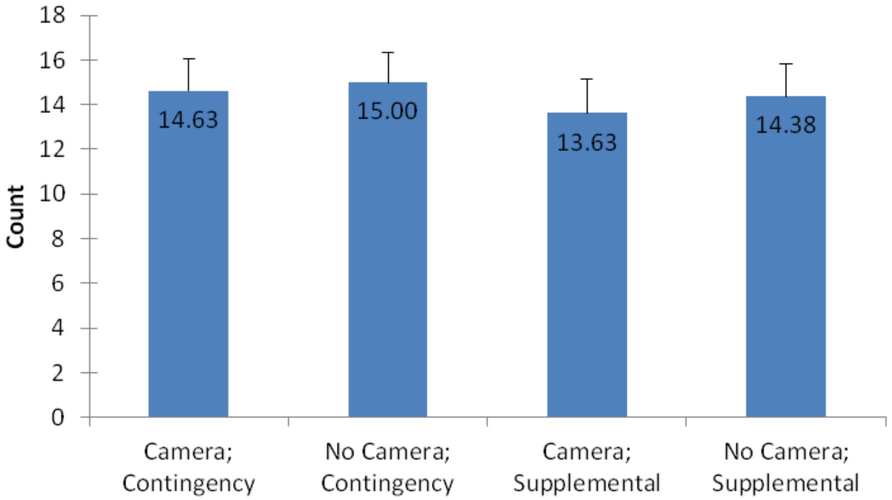

Figure 22. Average number of runway crossing commands.

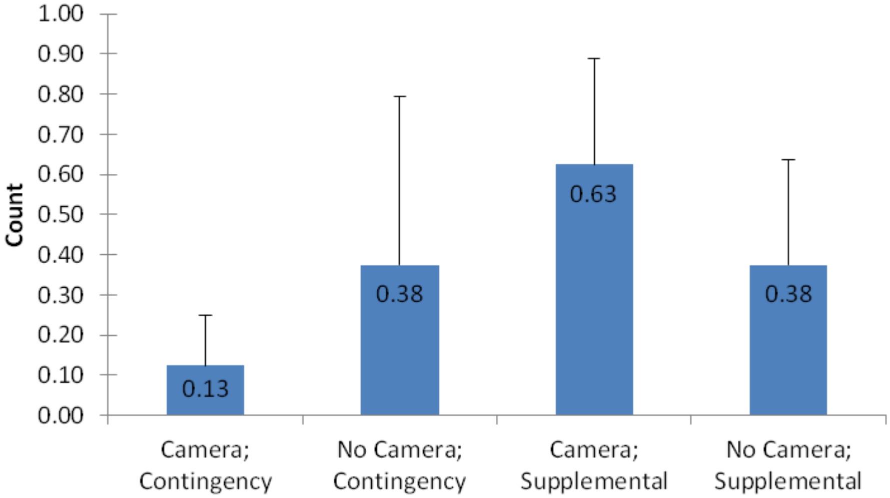

Figure 23. Average number of altitude commands.

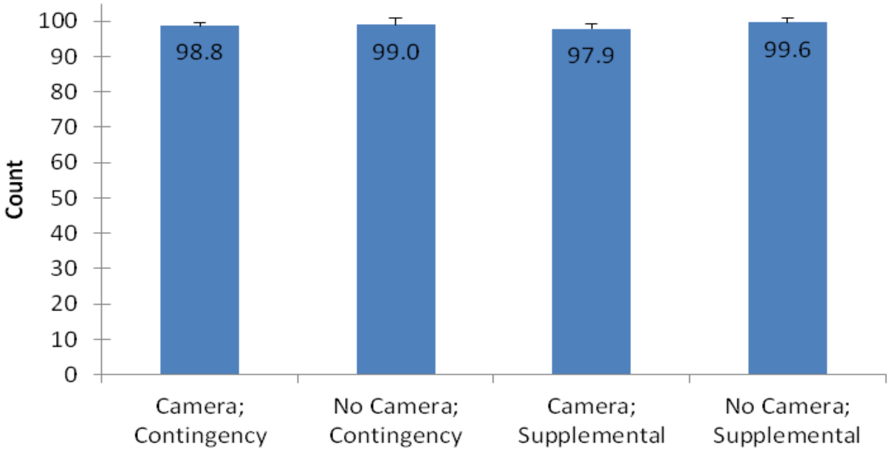

Figure 24. Average number of frequency change commands.

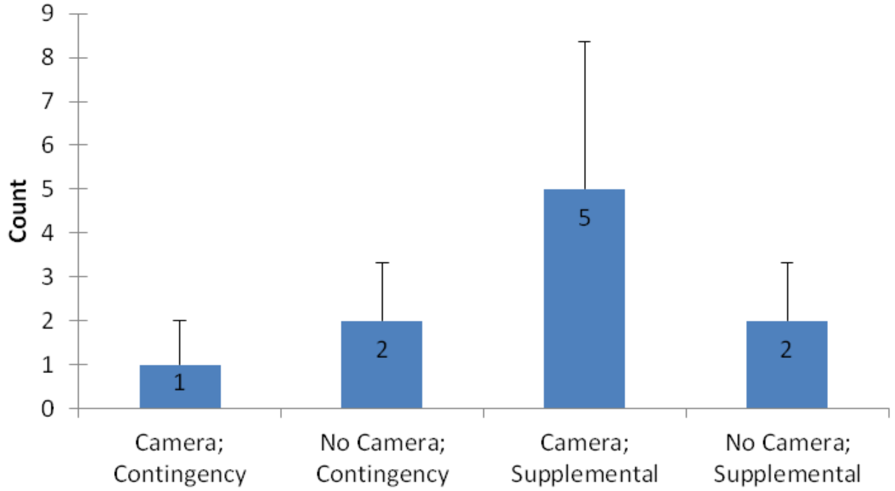

Figure 25. Total number of missed approach commands.

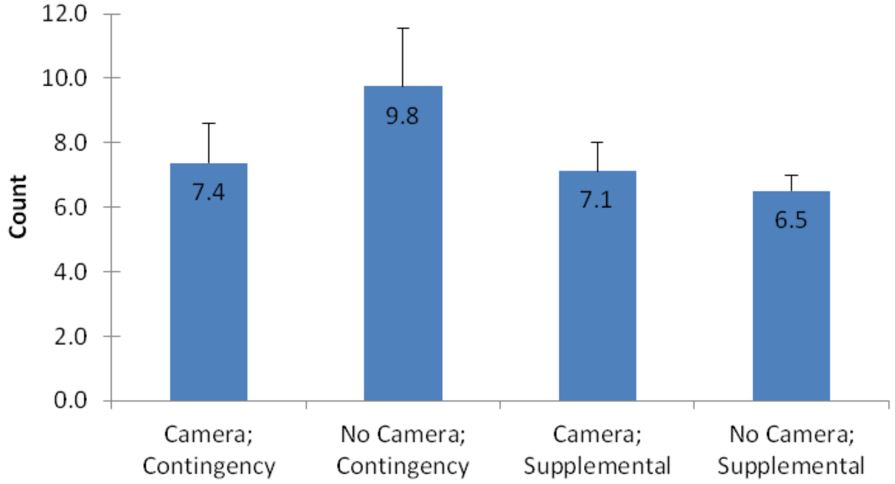

Figure 26. Average number of resume taxi commands.

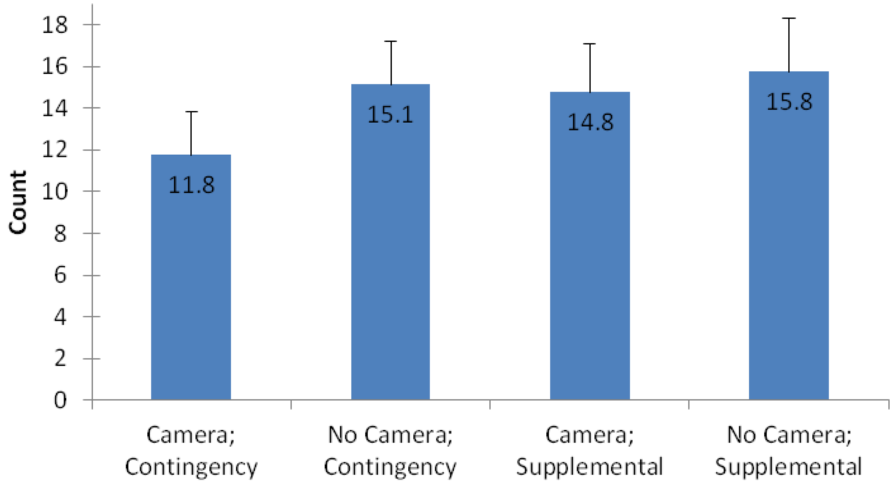

Figure 27. Average number of speed commands.

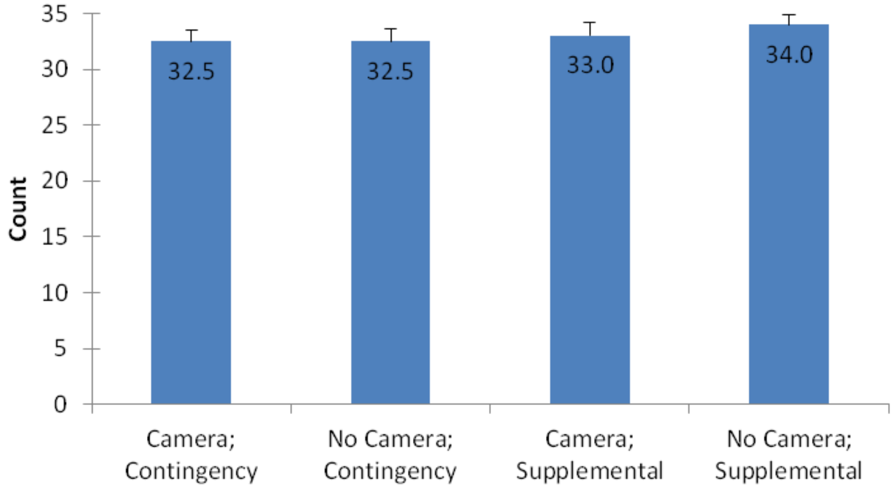

Figure 28. Average number of takeoff commands.

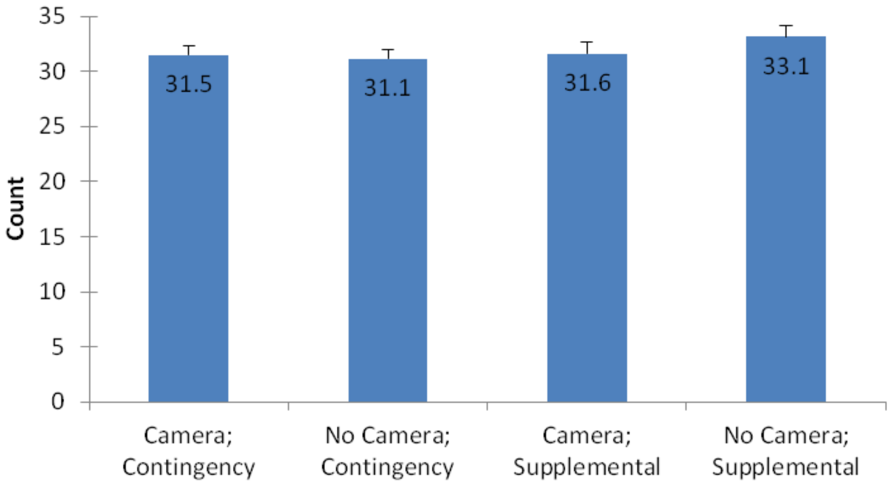

Figure 29. Average number of taxi-into-position-and-hold commands.

There were a number of commands where there were differences in the frequencies with which those commands were issued. For the average number of heading commands (see Figure 30), although not significant, there was a trend indicating that there were more heading commands issued by controllers in the Supplemental SNT condition than in the Contingency SNT condition, $F(1, 7) = 3.77$, $p = .09$, $\eta_p^2 = .35$.

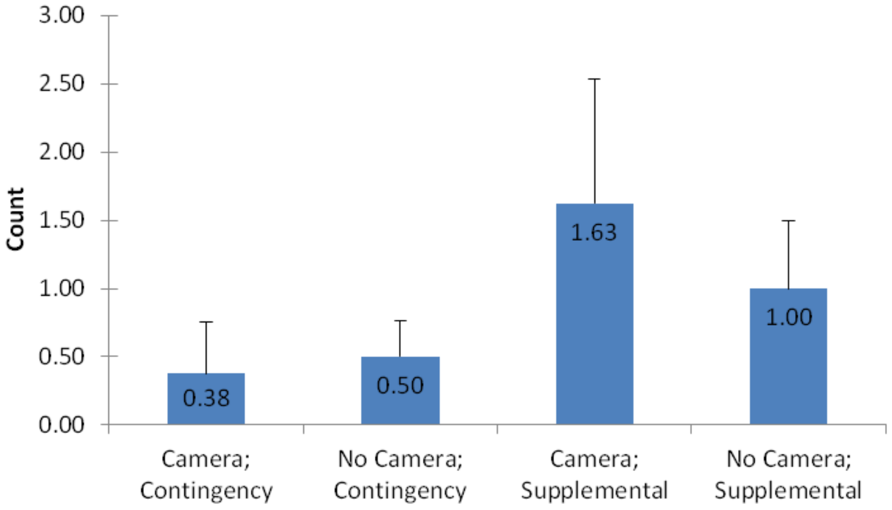

Figure 30. Average number of heading commands.

For the average number of stop commands (see Figure 31), although not significant, there was a trend indicating that there were fewer stop commands issued in the Supplemental SNT condition than in the Contingency SNT condition, $F(1, 7) = 3.90$, $p = .09$, $\eta_p^2 = .36$.

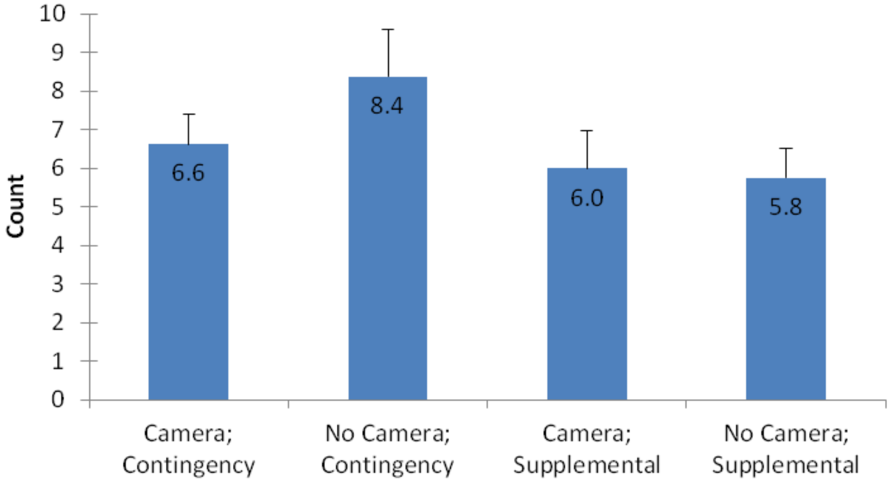

Figure 31. Average number of stop commands.

For the average number of hold short commands (see Figure 32) there were significantly fewer commands issued in the Supplemental SNT condition than in the Contingency SNT condition, $F(1, 7) = 7.19$, $p = .03$, $\eta_p^2 = .51$.

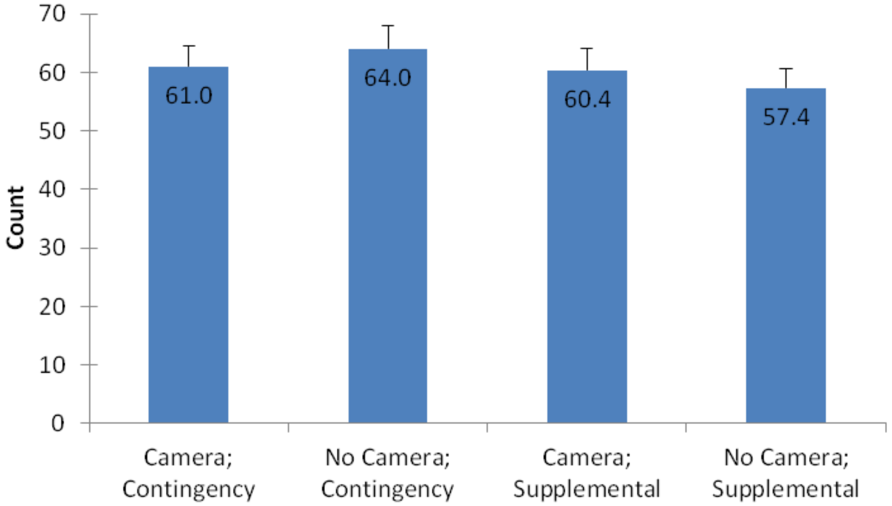

Figure 32. Average number of hold short commands.

For the average number of taxi commands (see Figure 33), there was a significant interaction between the SNT condition and the camera condition. When there was no camera, there did not appear to be a difference in the number of taxi commands issued, but when there were camera displays, there were more taxi commands issued in the Contingency SNT condition than in the Supplemental SNT condition, $F(1, 7) = 8.87$, $p = .02$, $\eta_p^2 = .56$.

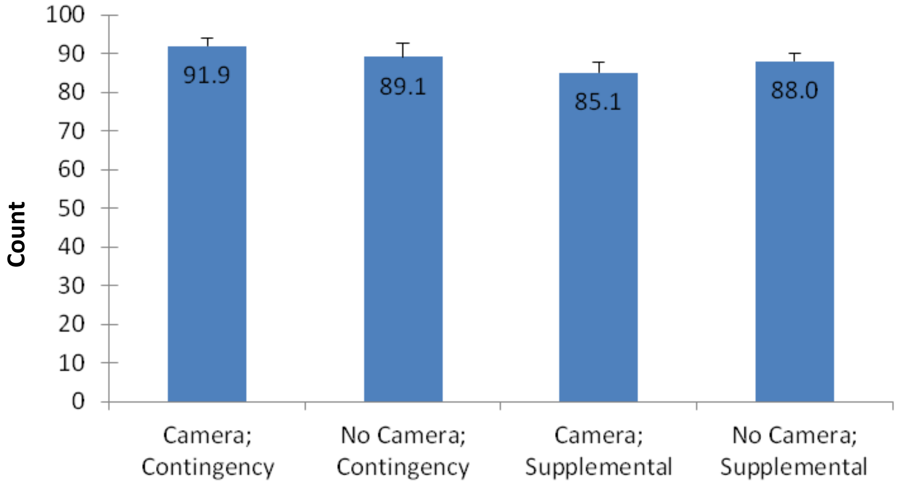

Figure 33. Average number of taxi commands.

3.3.5. Eye-tracking data: Standard eye-movement metrics

Because it was likely that eye- movement patterns and metrics would vary depending on whether the controller was working in the ground controller position or in the local controller position, we analyzed the data separately for each position. For the average saccade duration (see Figure 34) and number of blinks (Figure 35), there was no effect of SNT condition and no effect of camera availability for either the ground or local controller positions.

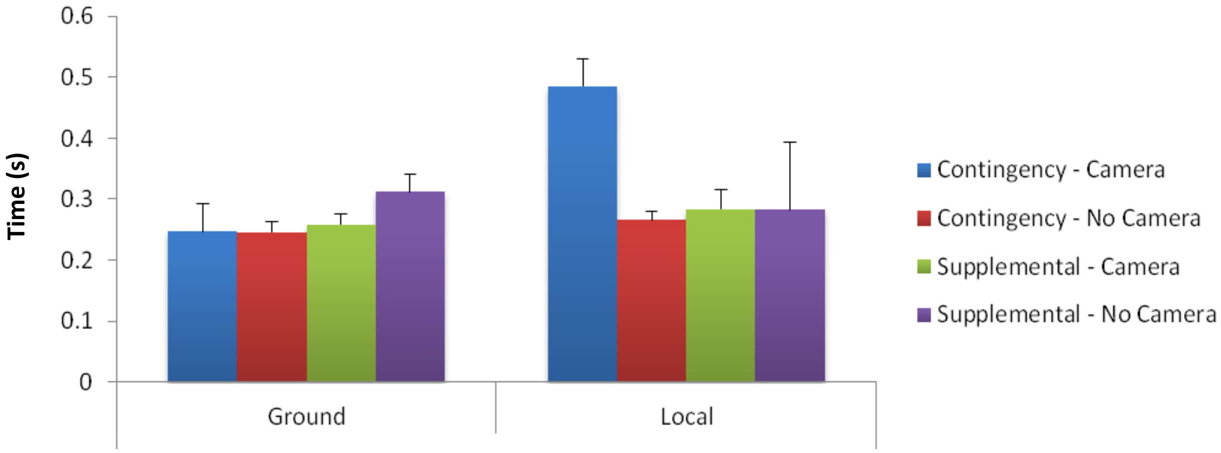

Figure 34. Average saccade duration by condition and position.

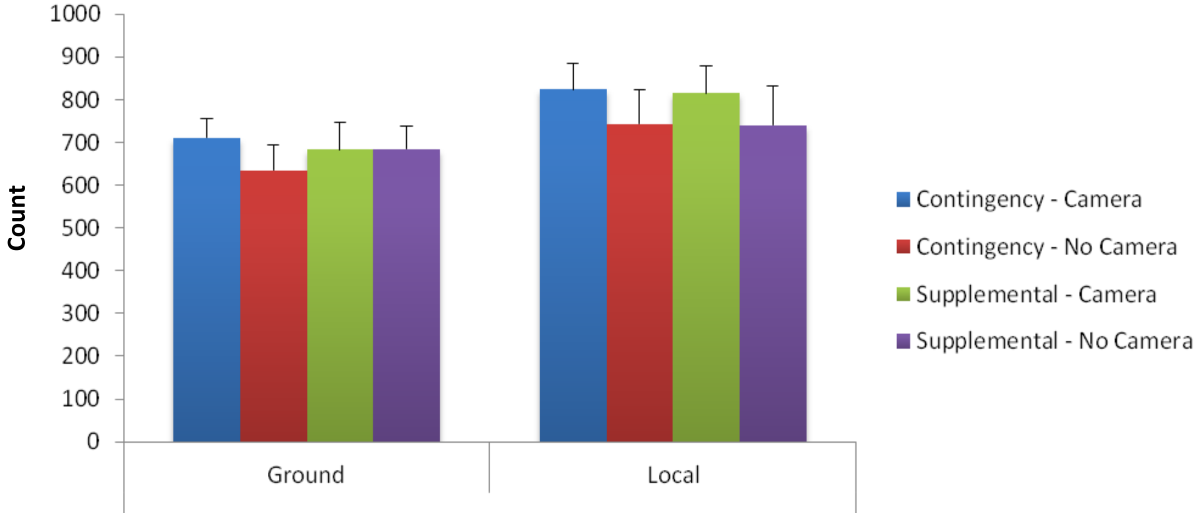

Figure 35. Average number of blinks by condition and position.

Saccade frequency has sometimes been found to correlate with workload, with frequency increasing with increasing workload (Zeghal, Grimaud, Hoffman, & Rognin, 2002). For the average number of saccades for the local controller, there was no effect of SNT condition and no effect of camera availability (see Figure 36). However, for the ground controller, there was a marginal effect of camera availability, $F(1, 5) = 5.24$, $p = .07$, $\eta_p^2 = .512$, with more saccades made in the no camera condition than in the camera condition.

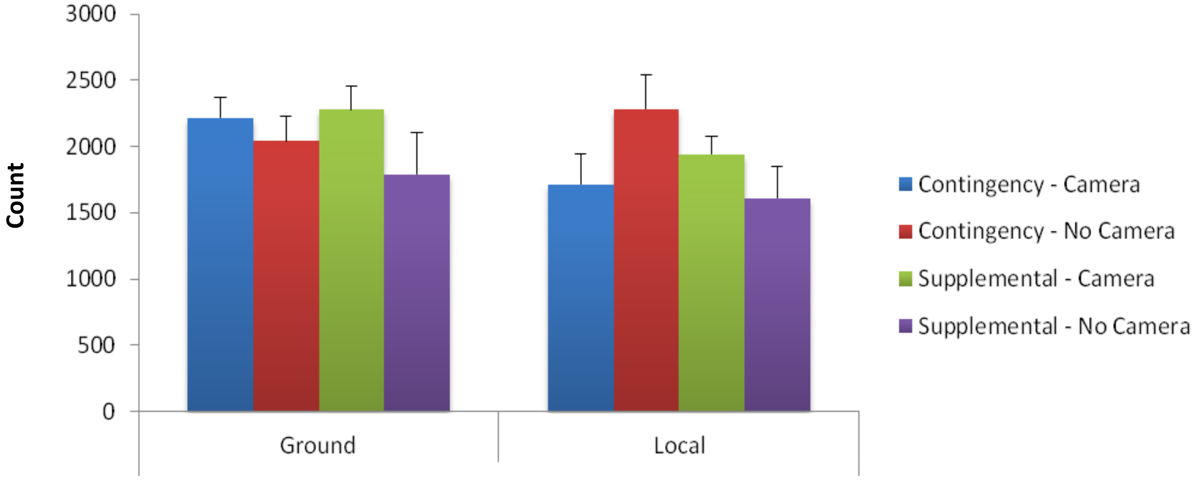

Figure 36. Average number of saccades by condition and position.

Saccade distance also has been found to be correlated with workload, with shorter distances being correlated with higher aircraft density and, therefore, higher workload (Ahlstrom & Friedman-Berg, 2005; Van Orden, Limbert, Makeig, & Jung, 2001). For the average saccade distance, there was no effect of either camera availability or SNT condition for the local controller (see Figure 37). However, for the ground controller there was an effect of SNT condition on average saccade distance. The saccades made by controllers in the Contingency SNT condition, were shorter than the saccades made by controllers in the Supplemental SNT condition, $F(1, 5) = 10.77$, $p = .02$, $\eta_p^2 = .68$, indicating higher workload for the ground controllers in the Contingency SNT condition than in the Supplemental SNT condition. This finding is tempered by the caveat that there was no OTW view in the Contingency condition. Therefore, shorter saccades may simply be the result of having less to look at in this condition. However, mean distance only increased about 1 inch between the Contingency and Supplemental SNT conditions, and we would expect a much bigger difference in saccade distance if the only factor affecting this result was controllers looking at the OTW view.

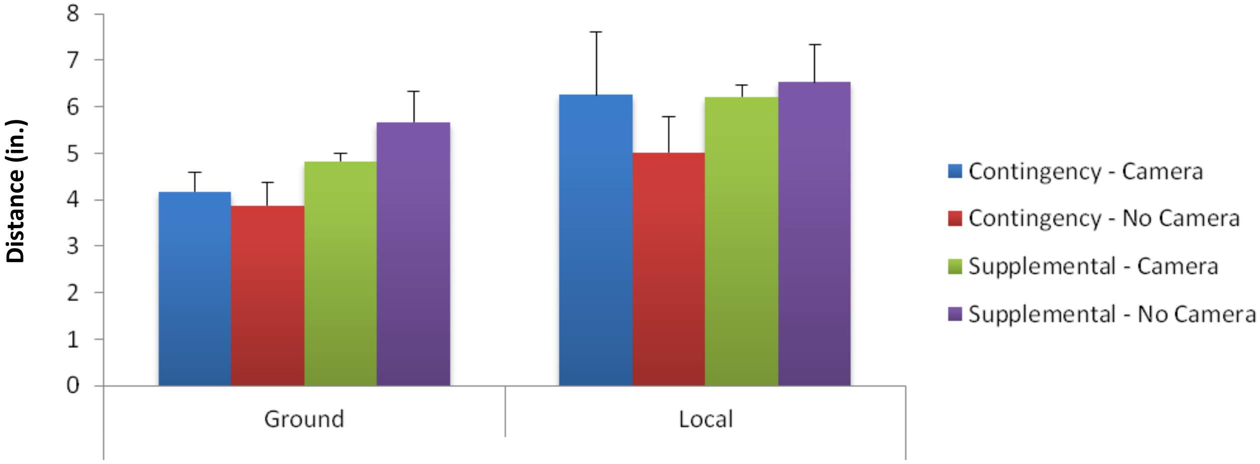

Figure 37. Average saccade distance by condition and position.

Blink duration has been found to be correlated with workload, with short blink durations being correlated with higher aircraft density (Ahlstrom & Friedman-Berg, 2005; Van Orden et al., 2001). For the average blink duration, there was no effect of either camera availability or SNT condition for the local controller (see Figure 38). However, for the ground controller, there was an effect of camera, $F(1, 5) = 7.48$, $p = .04$, $\eta_p^2 = .60$. The ground controllers had shorter blink durations with cameras than without cameras, indicating higher workload for the ground controller in the camera condition.

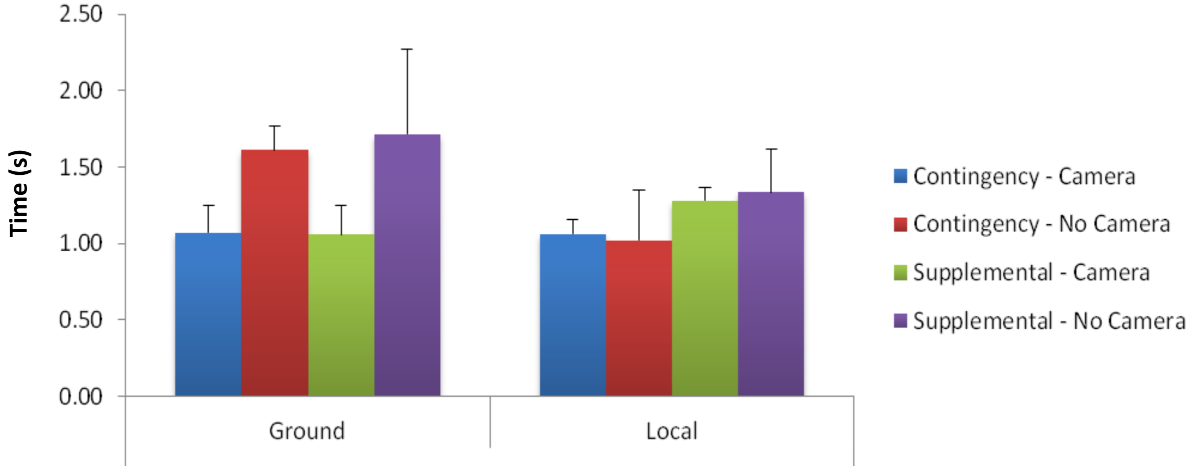

Figure 38. Average blink duration by condition and position.

Pupil diameter has also been used in air traffic control research as a correlate of workload, with larger pupil diameter being correlated with increasing workload as measured by the number of aircraft in the sector (Ahlstrom & Friedman-Berg, 2005; Iqbal, Adamczyk, Zheng, & Bailey, 2004; Iqbal, Zheng, & Bailey, 2004; Van Orden et al., 2001; Zeghal et al., 2002). For the average pupil diameter, there was no effect of SNT condition or camera availability for the ground controller (see Figure 39). However, for the local controller, there was an effect of the camera on pupil diameter, $F(1, 3) = 15.16$, $p = .03$, $\eta_p^2 = .84$. The average pupil diameter was smaller in the camera condition than in the no camera condition, indicating lower workload for the local controller in the camera condition.

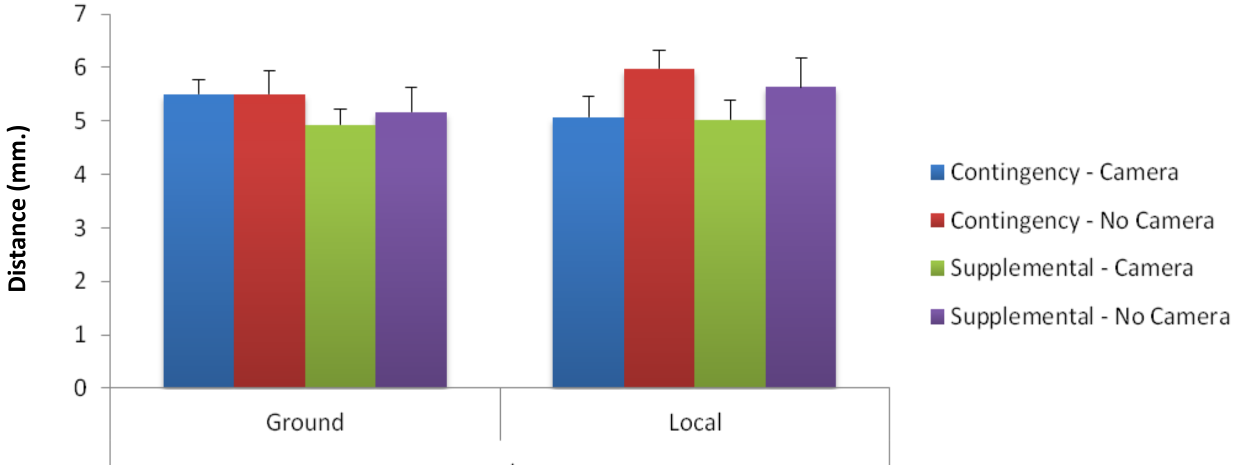

Figure 39. Average pupil diameter by condition and position.

For the average number of fixations, there was no effect of SNT condition or camera availability for the local controller (see Figure 40). However, there was a marginal effect of camera availability for the ground controller, $F(1, 5) = 6.16$, $p = .06$, $\eta_p^2 = .55$, with a higher average number of fixations in the camera condition than in the no camera condition.

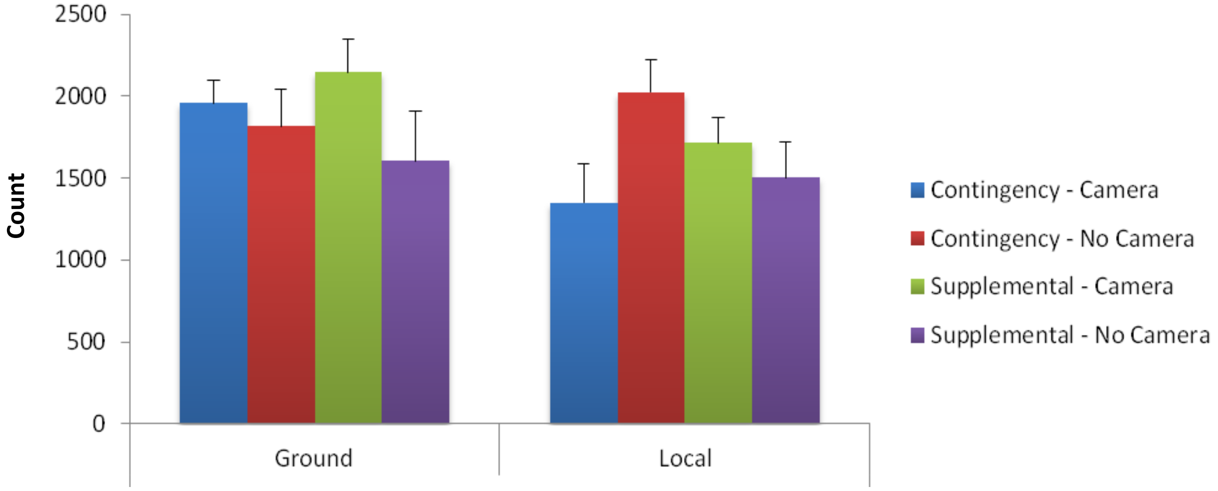

Figure 40. Average number of fixations by condition and position.

For the average fixation duration, there was no effect of SNT condition or camera availability for the ground controller (see Figure 41). However, there was a marginal effect on fixation duration of camera availability for the local controller, $F(1, 3) = 7.60$, $p = .07$, $\eta_p^2 = .72$. The local controller fixation durations were shorter, on average, in the camera condition than in the no camera condition.

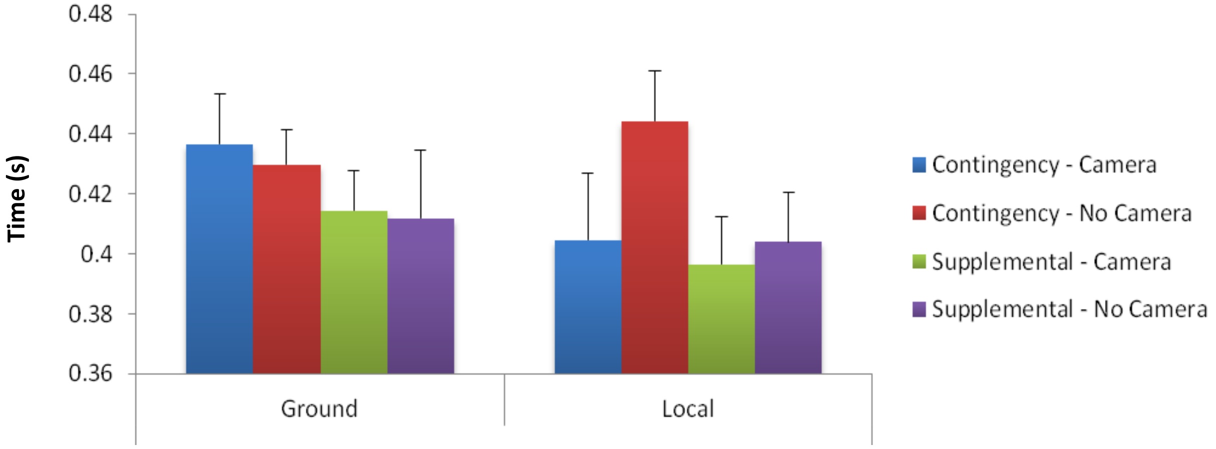

Figure 41. Average fixation duration by condition and position.

3.3.6. Analysis of fixation on AOIs

We analyzed the fixation data to determine the pattern of fixations on the different AOIs by the controllers across the different conditions. Patterns were analyzed separately for each controller position (i.e., ground and local) within each of the four AOIs (i.e., the TIDS display, the FDM display, the Camera display, and the OTW view).

For the local controller, we looked at the average number of fixations on the TIDS display (see Figure 42) and found a significant interaction between the SNT condition and camera availability, $F(1, 3) = 14.08, p = .03, \eta_p^2 = .82$. In the Contingency SNT condition, the controllers had more fixations on the TIDS in the no camera condition than in the camera condition, but in the Supplemental SNT condition, the controllers displayed the reverse pattern, with more fixations in the camera condition than in the no camera condition. On the FDM, there was no effect of SNT condition or camera condition on the number of fixations. For the number of fixations on the camera display, we compared only the Contingency SNT to the Supplemental SNT condition where the controllers had access to the camera, and we found no difference between the Contingency and Supplemental SNT conditions for number of fixations. For the number of fixations on the OTW view, we analyzed the data in the Supplemental SNT condition when the OTW view was available, and we found no difference in number of fixations for the different camera conditions.

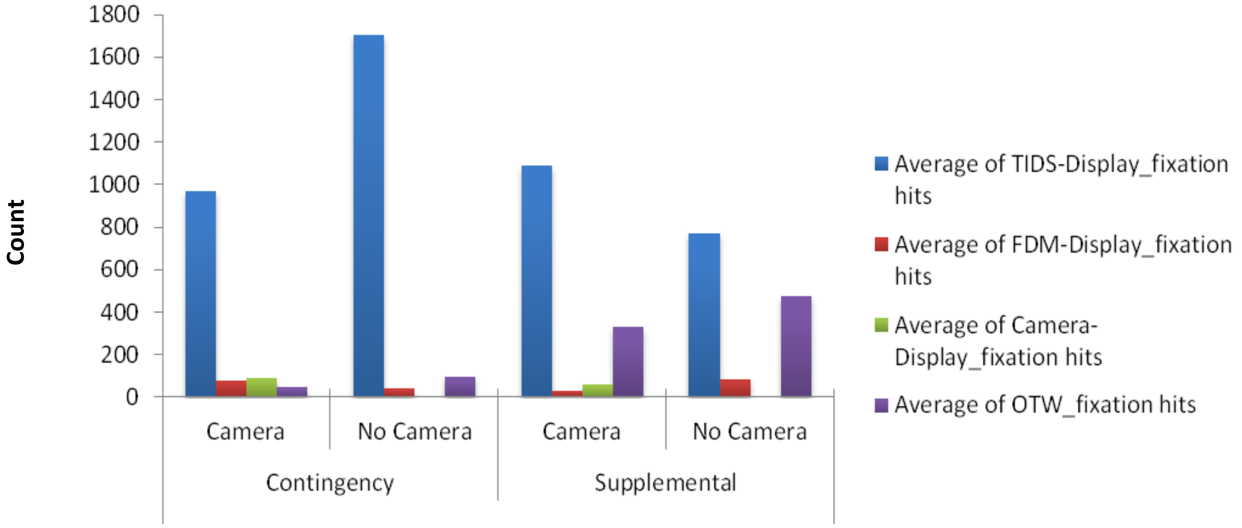

Figure 42. Average number of fixations on AOIs by condition for the local controller.

For the ground controller, looking at the average number of fixations on the TIDS display (see Figure 43), we found a marginal effect of SNT condition, $F(1, 5) = 4.14, p = .10, \eta_p^2 = .45$. Although not significant, there were a smaller average number of fixations on the TIDS display in the Supplemental SNT condition than in the Contingency SNT condition. For the number of fixations on the FDM, there was also a marginal effect of SNT condition for the ground controller, $F(1, 5) = 5.53, p = .07, \eta_p^2 = .53$. Again, although not significant, there were more fixations on the FDM display in the Supplemental SNT condition than in the Contingency SNT condition. When comparing the two camera conditions, we found no effect of SNT condition on the number of fixations on the camera display. When comparing the two Supplemental SNT conditions, we found no effect of camera availability on the number of OTW fixations.

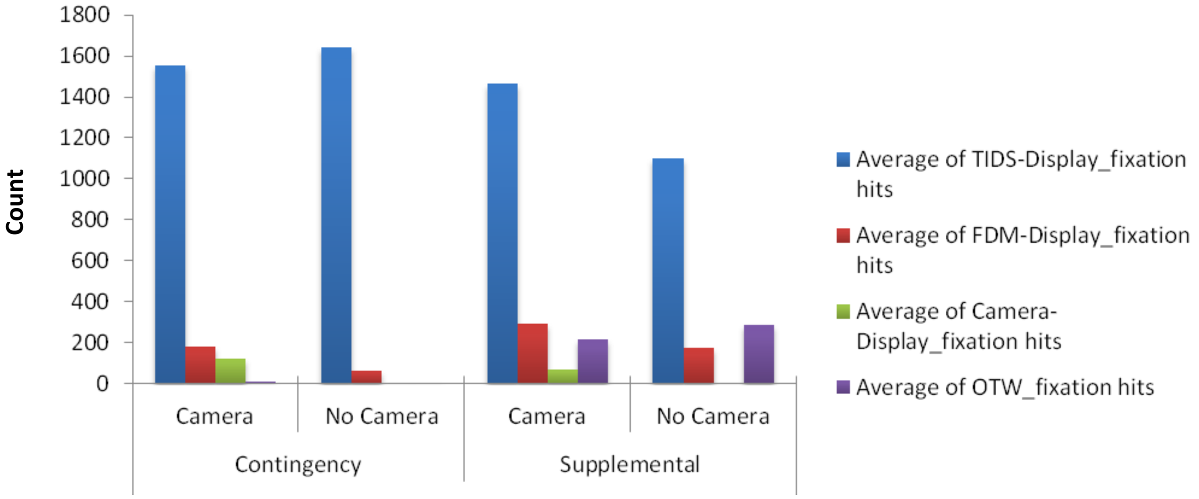

Figure 43. Average number of fixations on AOIs by condition for the ground controller.

We next analyzed the patterns of the average number of saccades on the different displays of interest for the local controller (see Figure 44). For the number of saccades on the TIDS, we found a significant interaction between the SNT condition and camera availability, *F*(1, 3) = 14.87, *p* = .03, η_p^2 = .83. In the Contingency SNT condition, the controllers made more saccades on the TIDS in the no camera condition than in the camera condition, but in the Supplemental SNT condition, the controllers displayed the reverse pattern, with a higher average number of saccades in the camera condition than in the no camera condition. Not surprisingly, this mirrored the pattern for the number of fixations on the TIDS for the local controller. For the number of saccades on the FDM, there was no effect of SNT condition or camera availability. When comparing the two camera conditions, we found no effect of SNT condition on the number of saccades on the camera display. When comparing the two Supplemental SNT conditions, we found no effect of camera availability on the number of saccades on the OTW view.

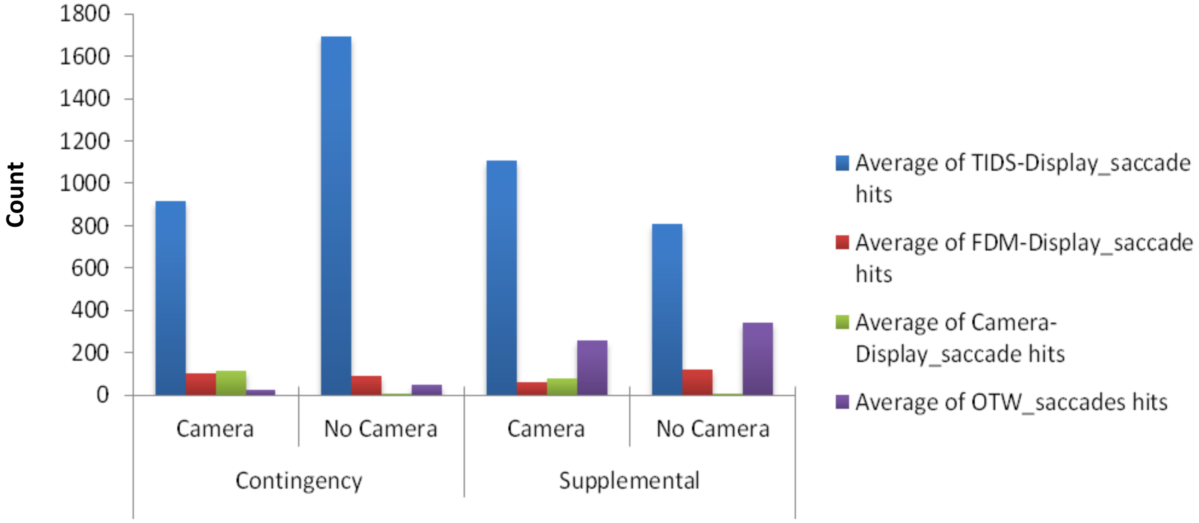

Figure 44. Average number of saccades on AOIs by condition for the local controller.

We also analyzed the patterns of the average number of saccades on the different displays of interest for the ground controller (see Figure 45). For the number of saccades on the TIDS, we found a marginal effect of SNT condition, *F*(1, 5) = 4.10, *p* = .10, η_p^2 = .45. In the Contingency SNT condition, although not significant, the controllers made more saccades on the TIDS than in the Supplemental SNT condition. For the number of saccades on the FDM, there was no effect of SNT condition or camera availability. When comparing the two camera conditions, we found no effect of SNT condition on the number of saccades on the camera display. When comparing the two Supplemental SNT conditions, we found no effect of camera availability on the number of saccades on the OTW view.

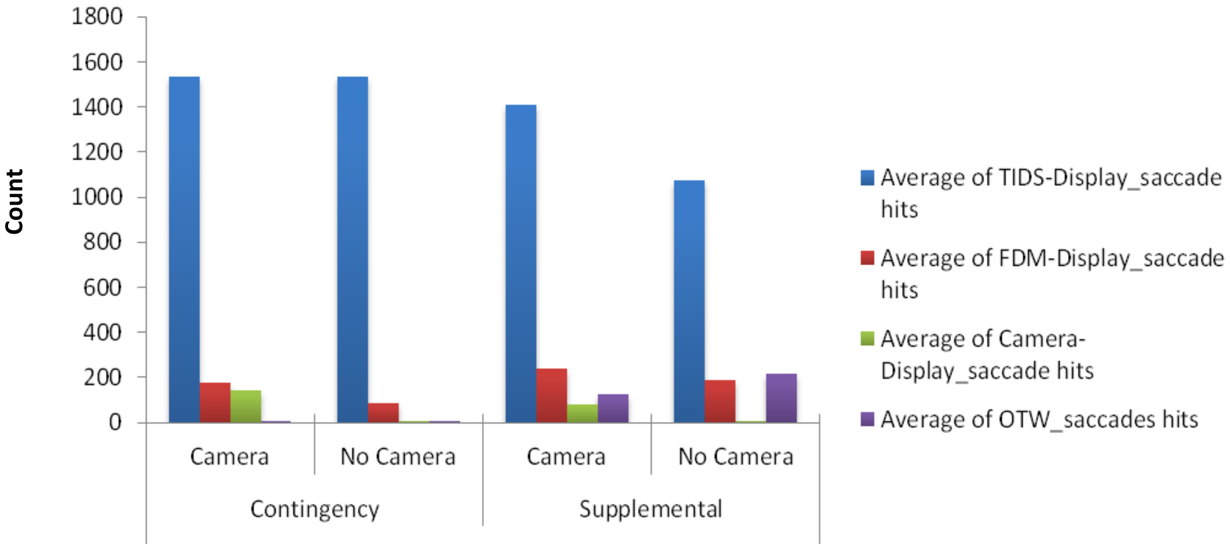

Figure 45. Average number of saccades on AOIs by condition for the ground controller.

We looked at the proportion of fixations on the different displays of interest for the local controller (see Figure 46). For the TIDS display, there was a significant interaction between SNT condition and camera condition, *F*(1, 3) = 11.54, *p* = .04, η_p^2 = .79. In the Contingency SNT condition, there was a higher proportion of fixation on the TIDS display in the no camera condition than in the camera condition, but in the Supplemental SNT condition, there were a higher proportion of fixations on the TIDS display in the camera condition than in the no camera condition. For the FDM display for the local controller, there was no effect of either SNT condition or camera availability. We compared the proportion of fixations on camera display for the two camera conditions and found no effect of SNT condition. We also compared the proportion of fixations on the OTW view for the two Supplemental SNT condition and found no effect of camera availability.

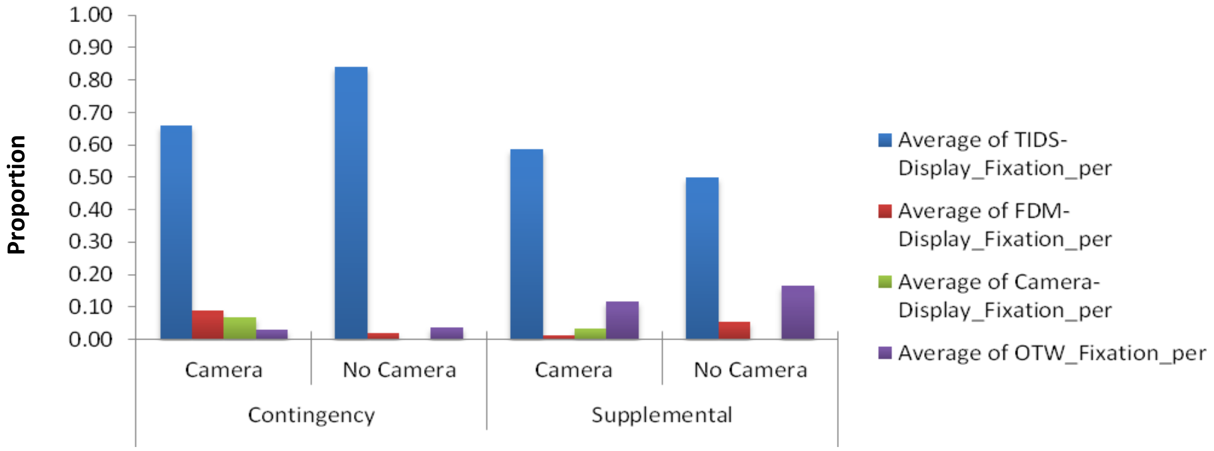

Figure 46. Average proportion of fixations made on AOIs by condition for the local controller.

We analyzed the proportion of fixations on the different displays of interest for the ground controller (see Figure 47). For the TIDS display, there was a significant interaction between SNT condition and camera condition, *F*(1, 5) = 12.67, *p* = .02, η_p^2 = .72. In the Contingency SNT condition, there was a higher proportion of fixation on the TIDS display in the no camera condition than in the camera condition, but in the Supplemental SNT condition, there was little difference in the proportion of fixations on the TIDS display in the different camera conditions. For the proportion of fixations on the FDM display made by the ground controller, there was a marginal effect of SNT condition, *F*(1, 5) = 4.08, *p* = .10, η_p^2 = .45. There were slightly more fixations on the FDM in the Supplemental SNT condition than in the Contingency SNT condition. We compared the proportion of fixations on camera display for the two camera conditions, and found no effect of SNT condition. We also compared the proportion of fixations on the OTW view for the two Supplemental SNT conditions and found an effect of camera availability, *t*(5) = 2.71, *p* = .04, mean difference = .07, 95% CI = [.003, .14], with more fixations on the OTW view in the no camera condition than in the camera condition.

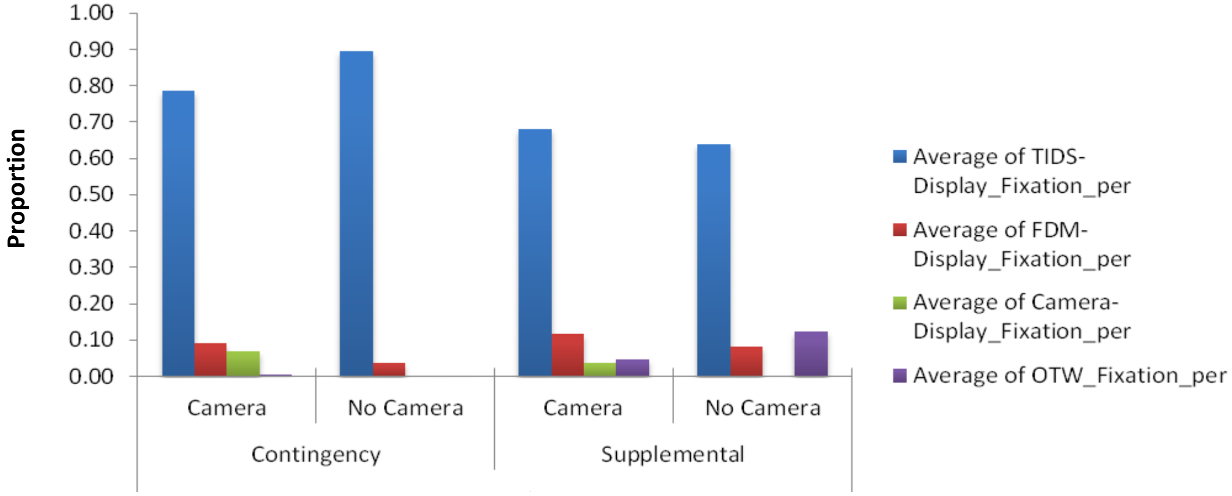

Figure 47. Average proportion of fixations made on AOIs by condition for the ground controller.

In addition to analyzing the proportion of fixations on each AOI, we also looked at the proportion of saccades on each AOI (see Figure 48). For the local controller, we found a significant interaction between the SNT conditions and the camera conditions for the proportion of saccades on the TIDS, *F*(1, 3) = 20.06, *p* = .02, η_p^2 = .87. For the Contingency SNT condition, there were a smaller proportion of saccades on the TIDS display in the camera condition than in the no camera condition, but for the Supplemental SNT condition there was little difference in the proportion of saccades on the TIDS in the two camera conditions. For the FDM display, there was no effect of SNT or camera conditions on the proportion of saccades. We compared the proportion of saccades on the camera display for the two camera conditions, and found no effect of SNT condition. We also compared the proportion of fixations on the OTW view for the two Supplemental SNT conditions and found no effect of camera availability.

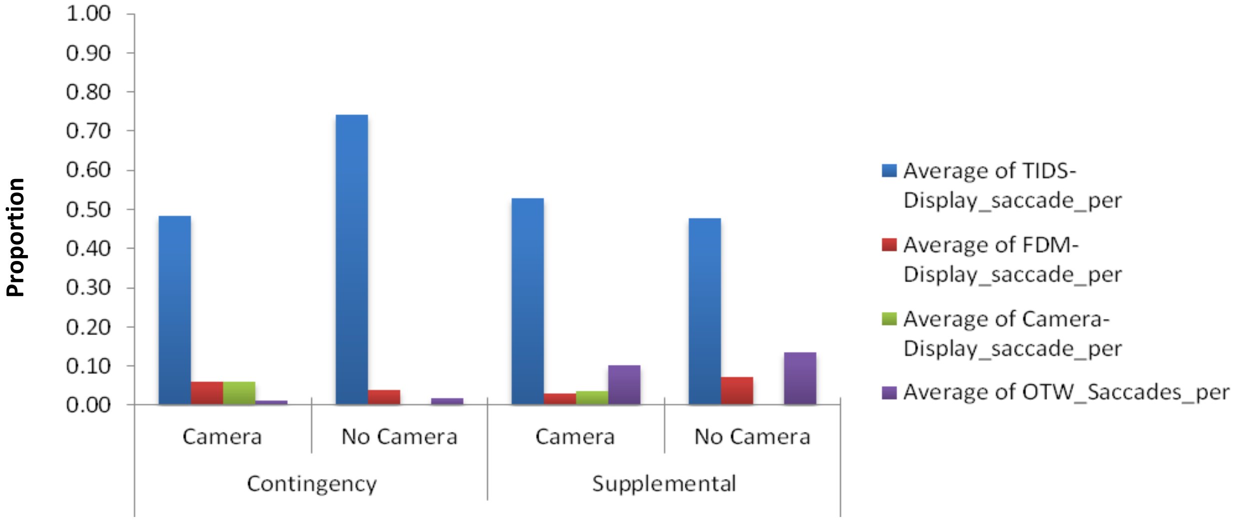

Figure 48. Average proportion of saccades made on AOIs by condition for the local controller.

For the ground controller, we found a significant effect of SNT condition on the proportion of saccades on the TIDS, *F*(1, 5) = 18.78, *p* = .007, η_p^2 = .79 (see Figure 49). There were a higher proportion of saccades on the TIDS in the Contingency SNT condition than in the Supplemental SNT condition. There was no effect of SNT or camera conditions on the proportion of saccades for the FDM display. We compared the proportion of saccades on the camera display for the two camera conditions, and found no effect of SNT condition. We compared the proportion of saccades on the OTW view for the two Supplemental SNT conditions and did find an effect of camera availability for the ground controller, *t*(5) = 3.26, *p* = .02, mean difference = .05, 95% CI =[.01, .08], with a higher proportion of saccades in the no camera condition than in the camera condition.

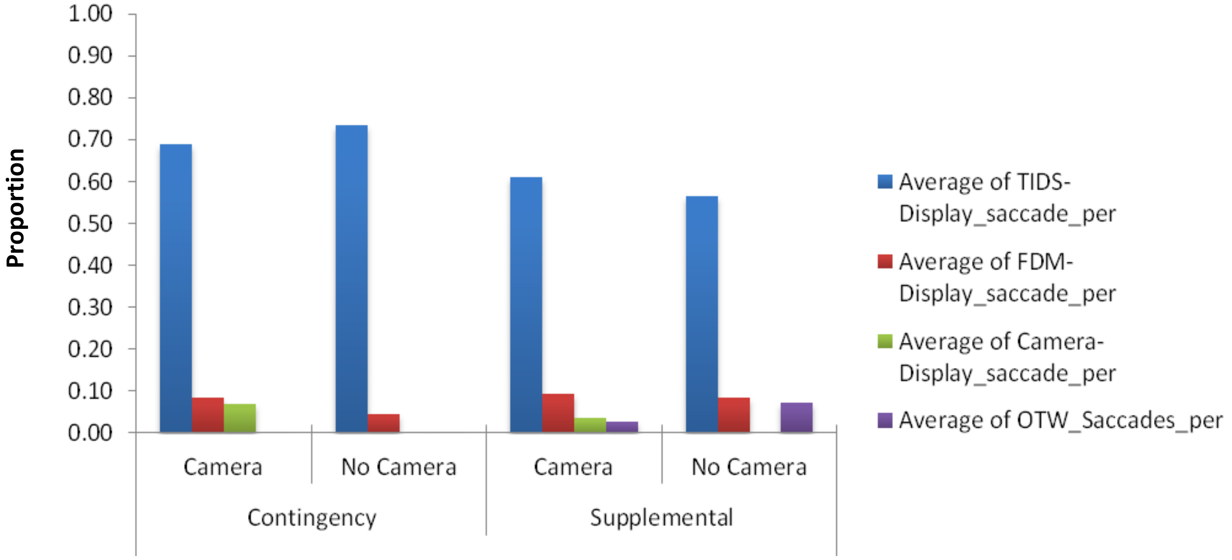

Figure 49. Average proportion of saccades made on AOIs by condition for the ground controller.

We next looked at the average fixation duration on each AOI (see Figure 50). For the local controller, we found a marginal effect of camera availability on the average fixation duration on the TIDS display, $F(1, 3) = 6.57$, $p = .08$, $\eta_p^2 = .69$. Fixations on the TIDS were slightly longer when there was no camera compared to when there was a camera. For the FDM, there was no effect of SNT condition or camera availability on the average fixation duration. For the camera display, there was no effect of SNT condition and for the OTW view; there was no effect of camera availability on the average fixation duration.

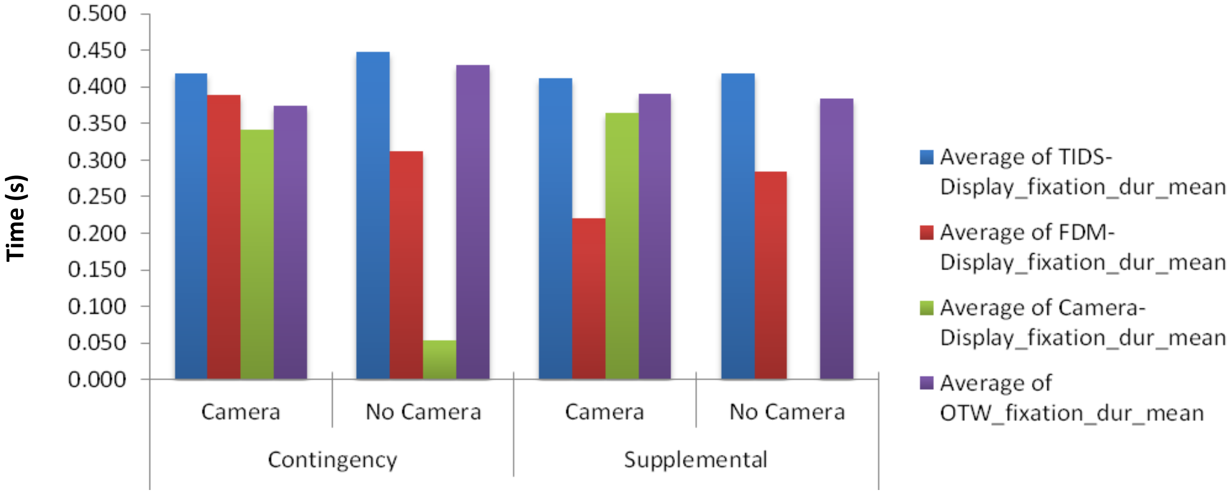

Figure 50. Average fixation duration on AOIs by condition for the local controller.

When we looked at the average fixation duration on each AOI for the ground controller (Figure 51), there was no effect of SNT condition or camera availability on the average fixation duration on the TIDS display. However, we did find a significant effect of camera availability on the average fixation duration on the FDM display, $F(1, 5) = 14.42$, $p = .01$, $\eta_p^2 = .74$, with longer fixation durations in the camera condition than in the no camera condition. For the camera display, there was no effect of SNT condition and for the OTW view there was no effect of camera availability on the average fixation duration.

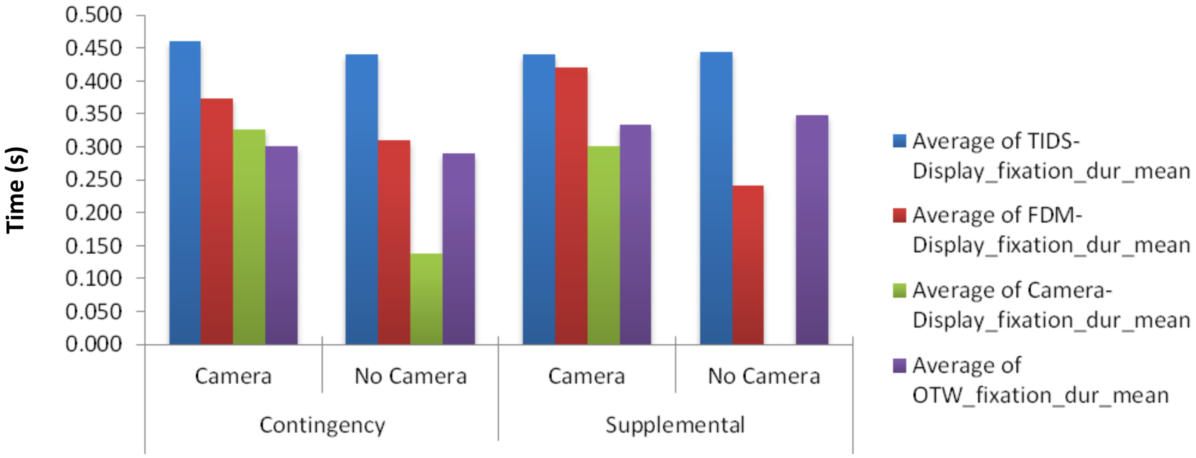

Figure 51. Average fixation duration on AOIs by condition for the ground controller.

We also looked at the average saccade duration on each AOI (see Figure 52). For the local controller, there was no effect of SNT condition or camera availability on the average saccade duration TIDS display or the FDM display. Also, for the camera display, there was no effect of SNT condition and for the OTW view there was no effect of camera availability on the average fixation duration.

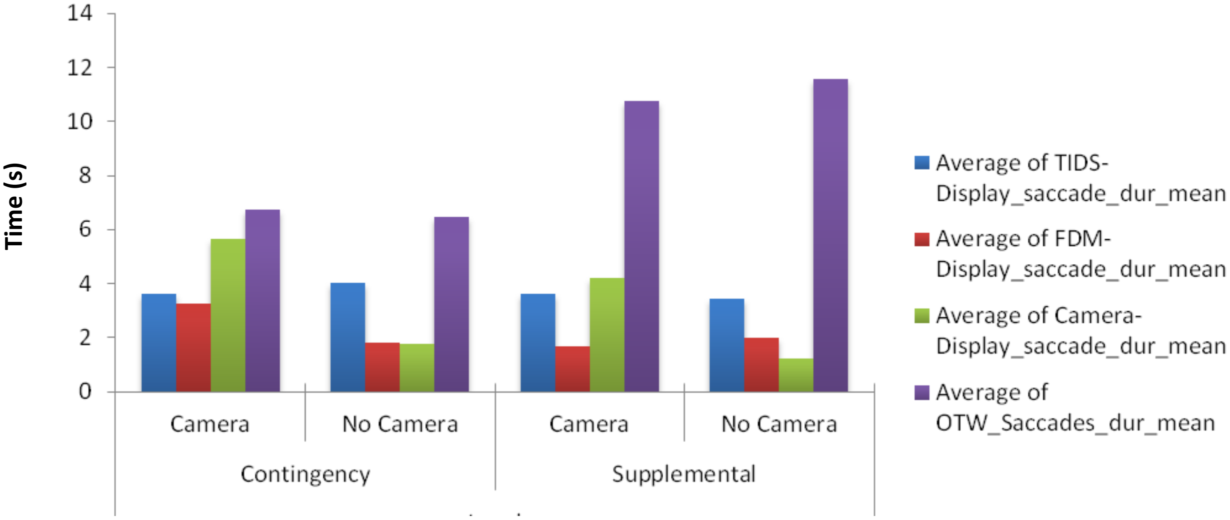

Figure 52. Average saccade duration on AOIs by condition for the local controller.

Looking at the average saccade duration on each AOI for the ground controller (see Figure 53), there was no effect of SNT condition or camera availability on the average saccade duration TIDS display. However, on the FDM display there was a marginal interaction effect between SNT conditions and camera conditions on the average saccade duration, $F(1, 5) = 5.90, p = .06, \eta_p^2 = .54$. Also, for the camera display, there was no effect on the average fixation durations on the camera display across the SNT conditions or on the OTW display for the different camera conditions.

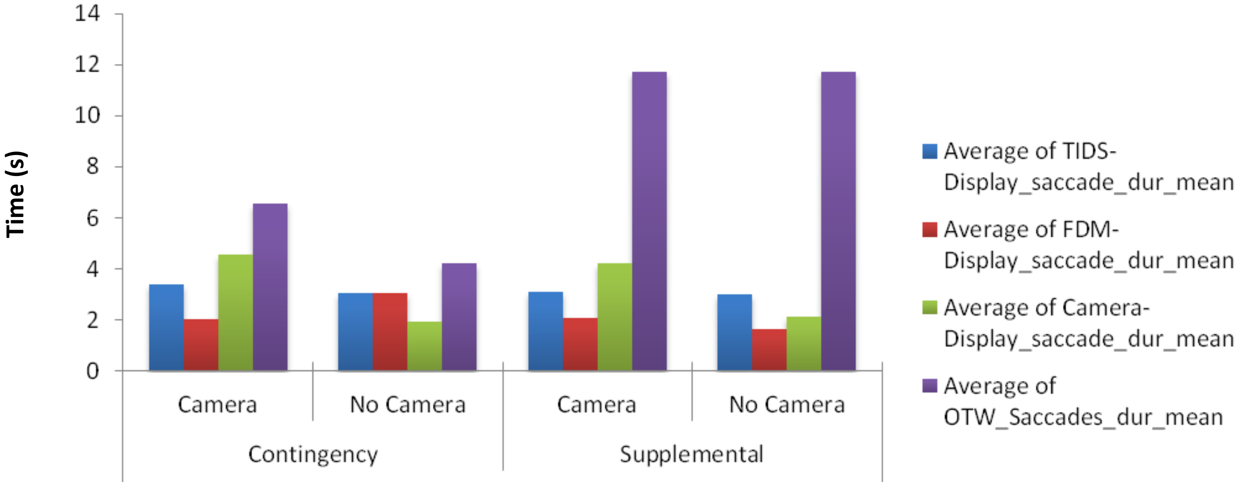

Figure 53. Average saccade duration on AOIs by condition for the ground controller.

We also looked at the fixation and saccade metrics for just the OTW display. We wanted to evaluate whether there were any differences in these metrics across the different camera conditions for the left, center, and right OTW display panels. For the average number of fixations (see Figure 54), we found no effect of camera availability on the number of fixations on left, center, or right OTW displays for either the ground or the local controller.

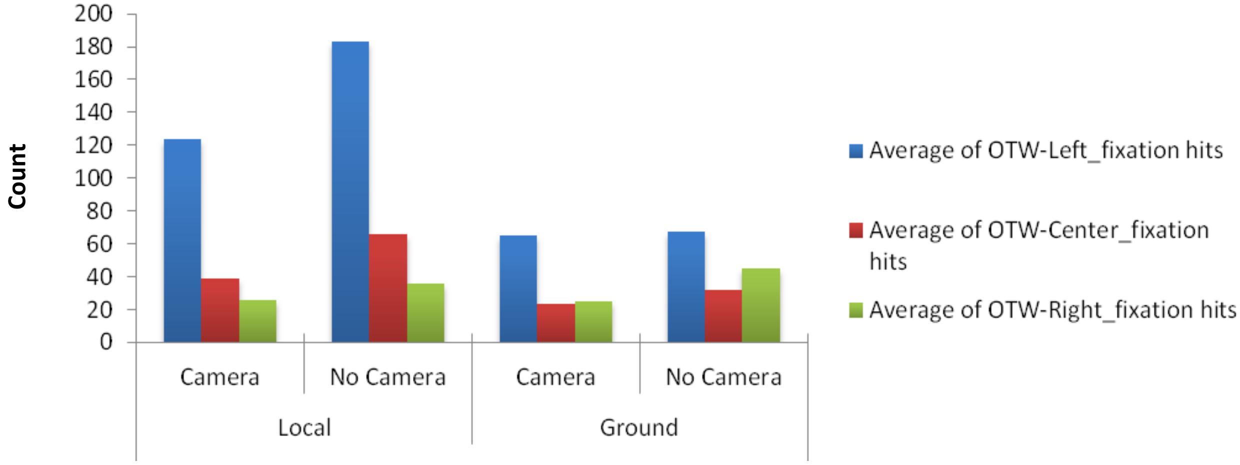

Figure 54. Average number of fixations on each OTW panel by condition for Supplemental SNT.

For the average number of saccades (see Figure 55), we also found no effect of camera availability on the number of fixations on left, center, or right OTW displays for either the ground or the local controller.

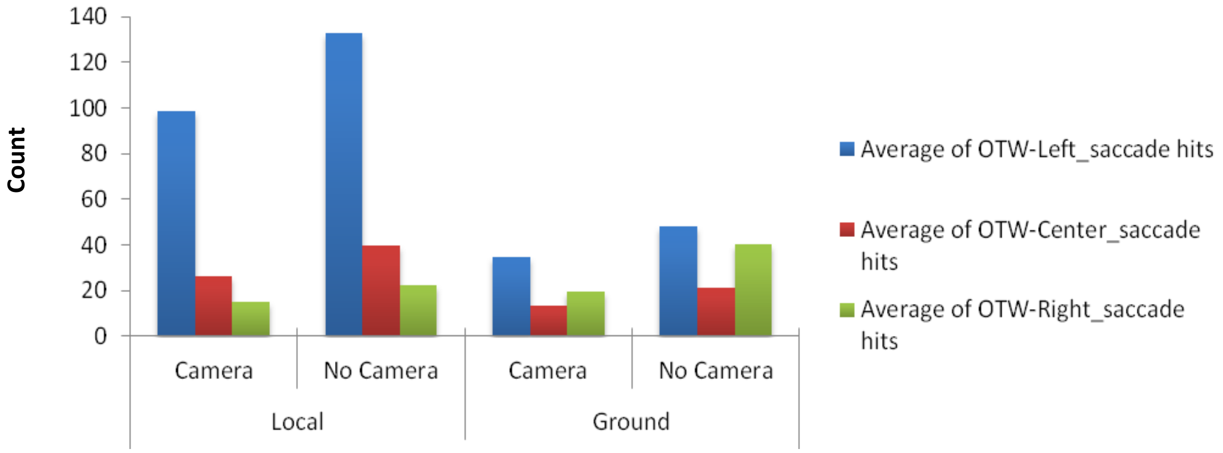

Figure 55. Average number of saccades on each OTW panel by condition and position for Supplemental SNT.

For the average proportion of fixations (see Figure 56), we found no effect of camera availability on the proportion of fixations on left, center, or right OTW displays for the local controller and no effect of camera availability on the proportion of fixations on left and right OTW displays for the ground controller. We did find a marginal effect of camera availability on the proportion of fixations on the center OTW display for the ground controller, $t(5) = 2.46$, $p = .06$, mean difference = .03, 95% CI = [-.001, .06].

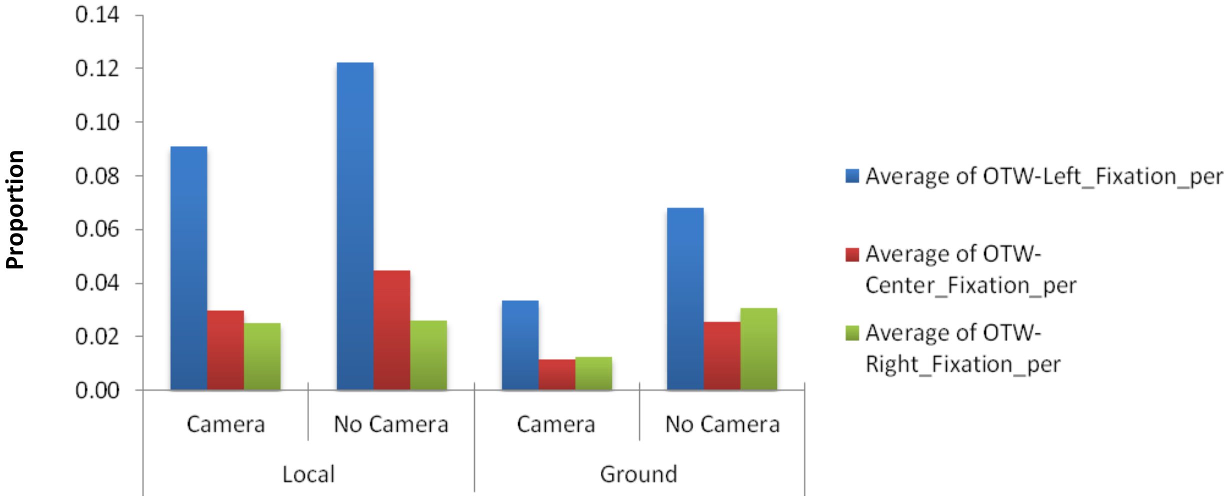

Figure 56. Average proportion of total fixations on each OTW panel by condition and position for Supplemental SNT.

For the average proportion of saccades (see Figure 57), we found no effect of camera availability on the proportion of saccades on the left, center, or right OTW displays for the local controller and no effect on the right OTW displays for the ground controller. We did find a marginal effect of camera availability on the proportion of saccades on both the left OTW display, *t*(5) = 2.29, *p* = .07, mean difference = .04, 95% CI = [-.006, .09]; and center OTW display, *t*(5) = 2.84, *p* = .04, mean difference = .02, 95% CI = [.002, .03] for the ground controller.

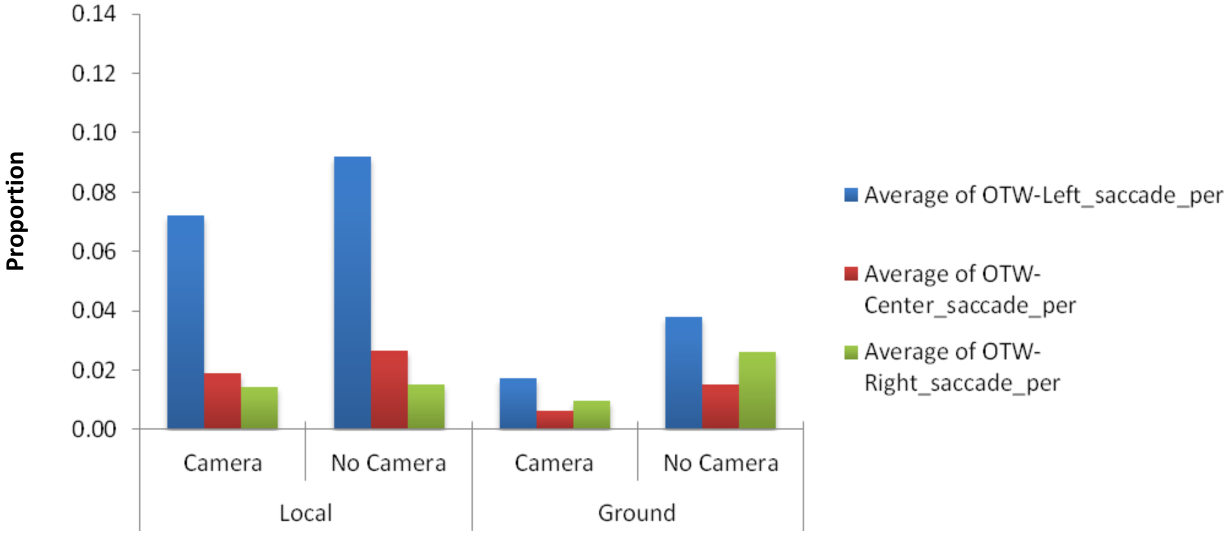

Figure 57. Average proportion of total saccades on each OTW panel by condition and position for Supplemental SNT.

For the average fixation duration (see Figure 58), we found no effect of camera availability on the fixation duration on left, center, or right OTW displays for the local controller and no effect of camera availability on the fixation duration on left and center OTW displays for the ground controller. We did find a marginal effect of camera availability on the average fixation duration on the right OTW display for the ground controller, *t*(5) = 2.64, *p* = .05, mean difference = .08, 95% CI = [.002, .16].

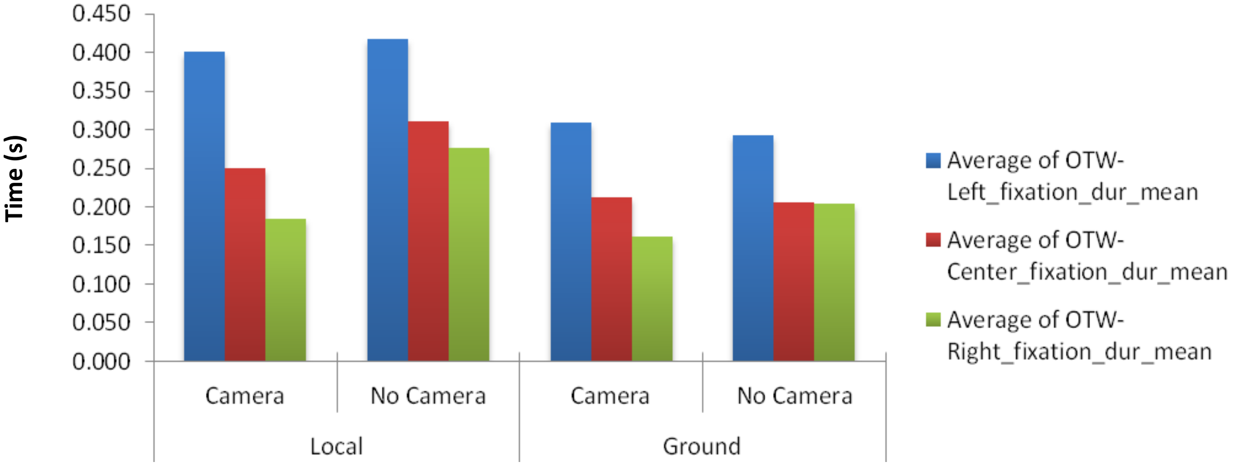

Figure 58. Average fixation duration for the OTW panels by condition and position for Supplemental SNT.

For the average saccade duration (see Figure 59), we found no effect of camera availability on saccade duration on left, center, or right OTW displays for either the ground or the local controller.

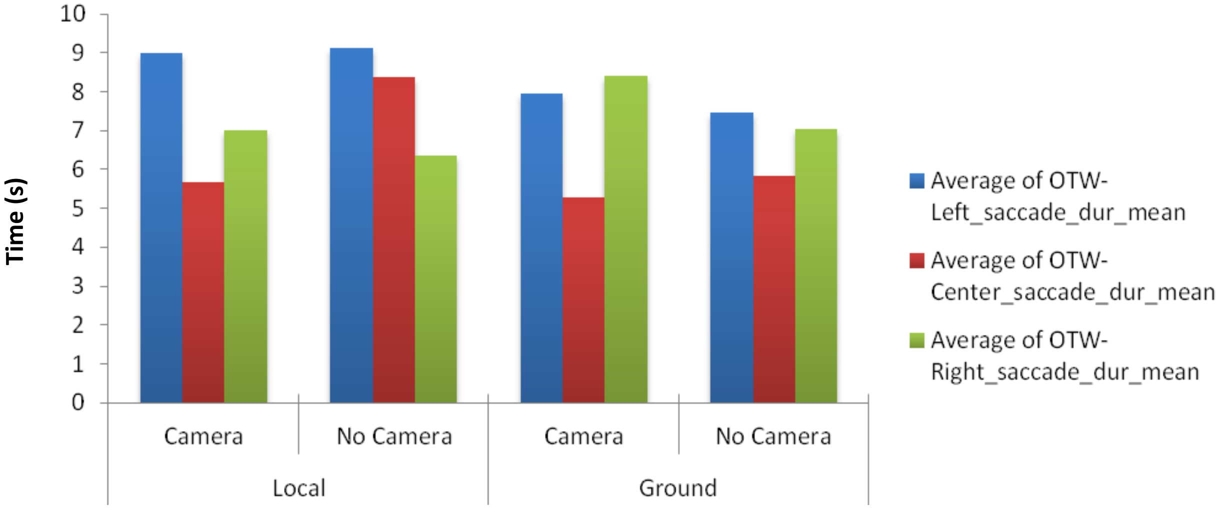

Figure 59. Average saccade duration for the OTW panels by condition and position for Supplemental SNT.

3.4. Post-Run Questionnaire Data

3.4.1. Camera-related questions

After each run, the controllers rated the degree to which the displays or camera views helped them maintain things like awareness of aircraft identity, location, predicted location, incursions, and a safe and efficient operation. Ratings were made on a scale from 1 to 7, with 1 indicating *very little* and 7 indicating *very much*.

The controllers gave median ratings of 7 for the TIDS for helping to identify aircraft, predict aircraft positions, predict traffic location, detect aircraft, detect incursions, detect off-nominals, and run safe and efficient operations in all conditions (Figures 60 through 66). The median ratings for the TIDS were consistently higher than the median ratings for the OTW, and the median ratings for TIDS were highest for detecting off-nominal events.

In only one instance did the controllers give a median rating of 7 for the OTW. This rating was for helping to maintain safe operations in the No Camera condition. Although lower than the TIDS ratings, the median OTW ratings were consistently high, with all questions receiving median ratings of 6 and above.

When the controllers were asked to rate the degree to which the displays or camera views helped maintain awareness of aircraft identity (see Figure 60), predict aircraft position (see Figure 61), maintain awareness traffic location (see Figure 62), detect aircraft (see Figure 63), maintain efficient operations (see Figure 64), maintain safe operations (see Figure 65), confirm potential runway incursions (see Figure 66), or detect any off-nominal responses (see Figure 67), most of the ratings of 4 or below were for the cameras and the FDM in the Supplemental condition when they had access to both the camera and the OTW view. This is likely because they found these tools to be less useful when both the TIDS and the OTW view were available. Additionally, the ratings for the auxiliary scanning camera were sometimes lower than for the PiP scanning camera.

Unlike SNT HITL 1.5 (Friedman-Berg et al., 2012), the controllers in SNT HITL 2 found it more useful to have the scanning camera window directly on the TIDS display. However, it is important to note that the controllers in SNT HITL 1.5 did not have intelligent logic driving the scanning feature. As noted earlier, the scanning camera in SNT HITL 2 automatically tracked aircraft arrivals and responded to alerts or off-nominal events by zooming to the aircraft involved in that event.

Ratings for the camera and its various inset windows were generally higher when there was no OTW view, likely because they provided a means by which controllers could maintain their situation awareness. Also, the PiP scanning camera ratings were higher for helping to maintain safe operations. With few exceptions, the lowest ratings were for the fixed camera windows and the FDM in the Camera/OTW condition.

We also performed statistical tests to evaluate whether ratings differed across conditions. For the TIDS and FDM, when there were ratings for all four conditions, we used the Friedman Test. For camera related ratings or OTW ratings for only two of the conditions we used the Wilcoxon Signed Rank Test.

There were no significant differences in the ratings across conditions for helping to maintain awareness of aircraft identity (Figure 60), predict aircraft position (see Figure 61), monitor traffic location (see Figure 62), maintain efficient operations (see Figure 64), maintain awareness of runway incursions (see Figure 66), or help detect off-nominal responses (see Figure 67) for either the TIDS or the FDM. For helping to detect aircraft (see Figure 63) and to maintain safe operations (Figure 65), there were no significant differences for the ratings for the TIDS display, but there were significant differences across conditions for the FDM display, $\chi^2_{detect\ aircraft}(3) = 10.15, p = .02$ and $\chi^2_{maintain\ safe\ operations}(3) = 8.66, p = .03$.

Also, for the OTW display, auxiliary camera display, auxiliary scanning camera window, fixed camera window, panoramic camera window, and the PiP camera window, there were no significant differences in ratings across conditions.

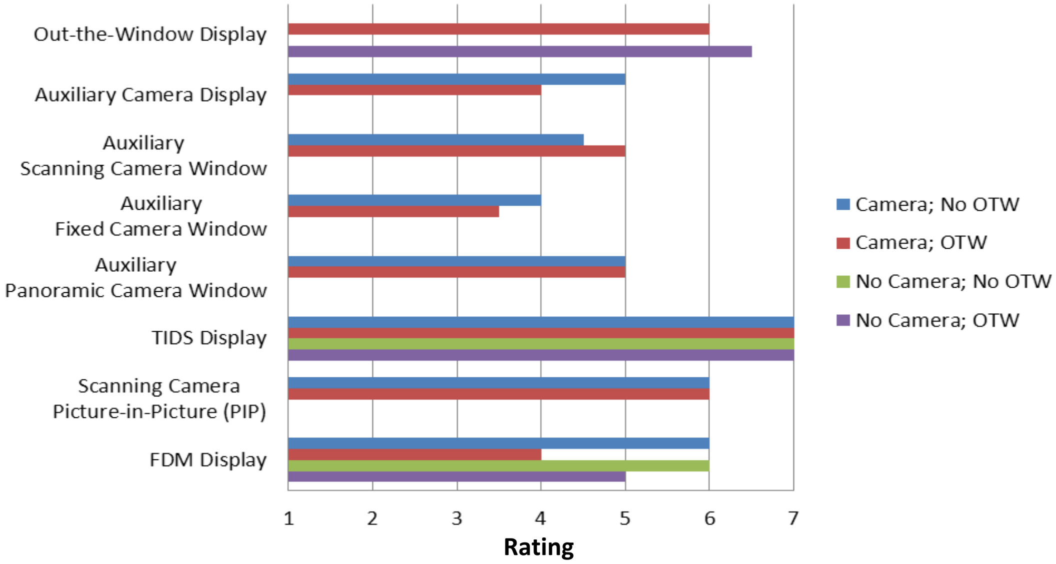

Figure 60. Median ratings for helping to identify aircraft by display or camera type.

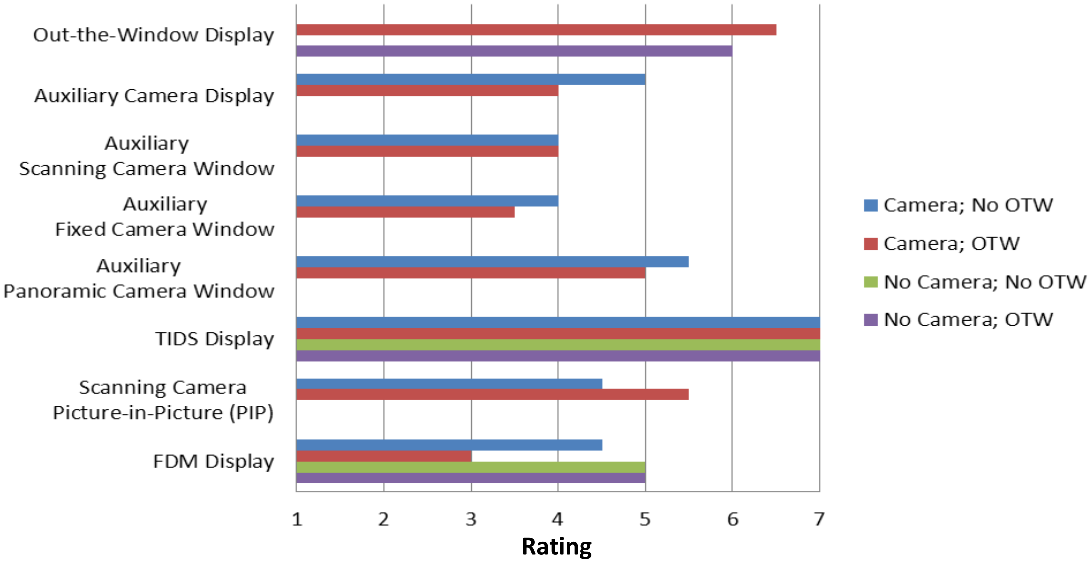

Figure 61. Median ratings for helping to predict position by display or camera type.

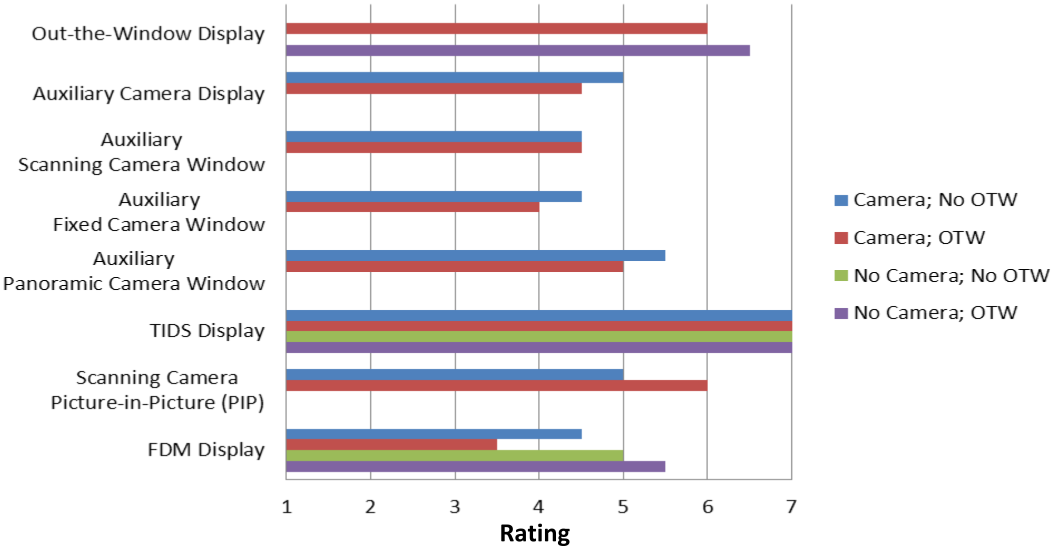

Figure 62. Median ratings for helping to monitor traffic location by display or camera type.

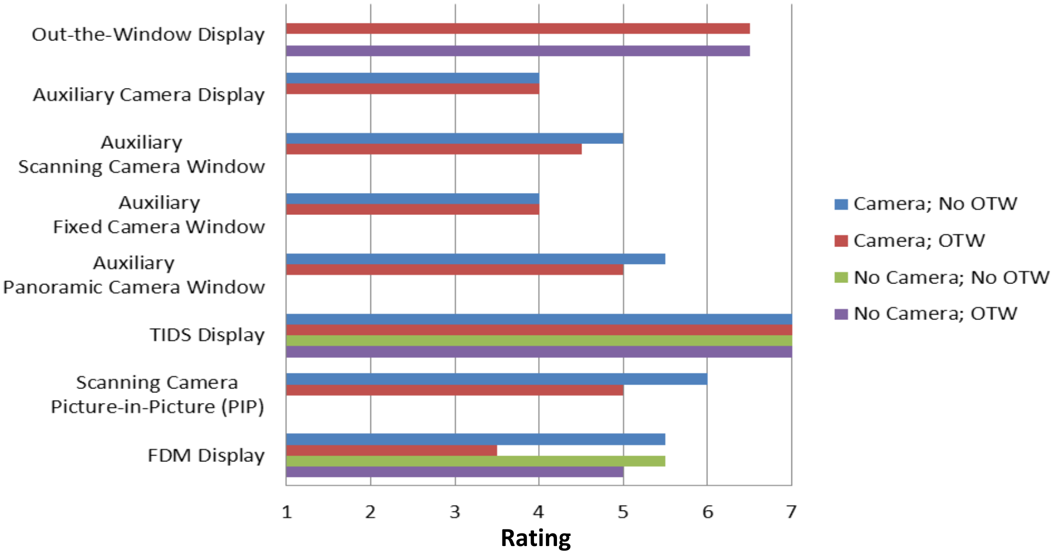

Figure 63. Median ratings for helping to detect aircraft by display or camera type.

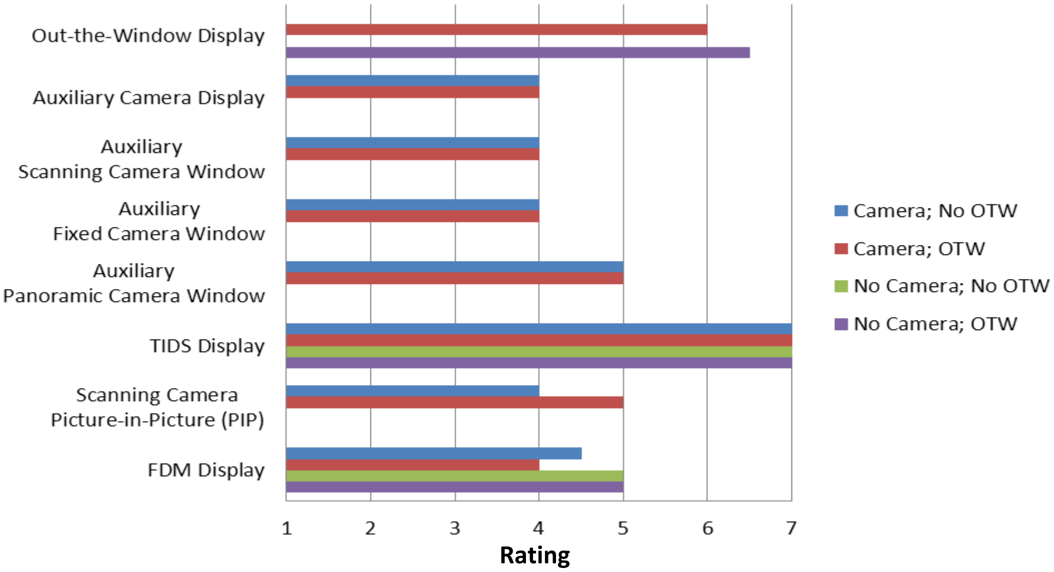

Figure 64. Median ratings for helping to maintain efficient operations by display or camera type.

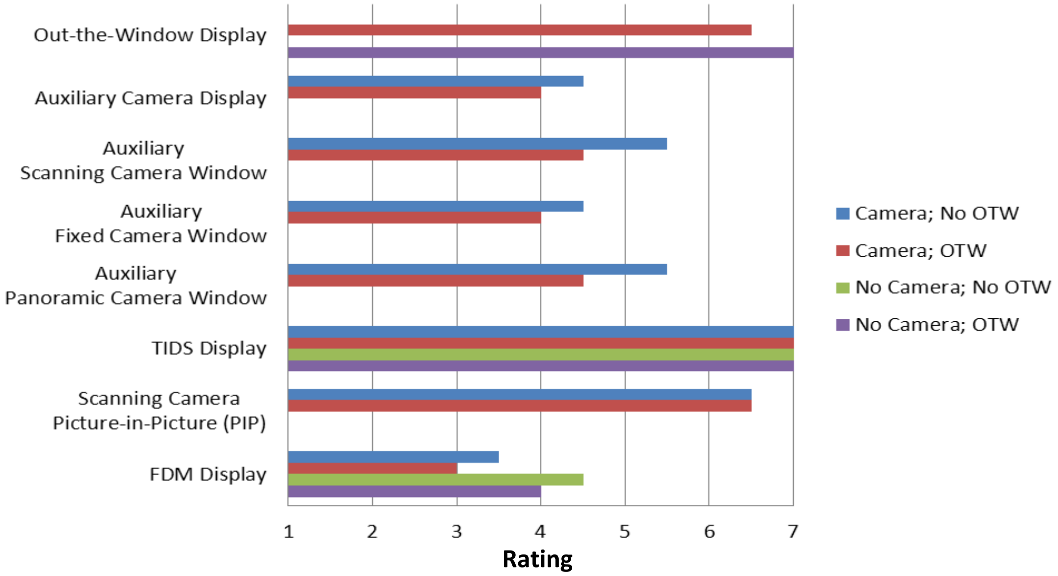

Figure 65. Median ratings for helping to maintain safe operations by display or camera type.

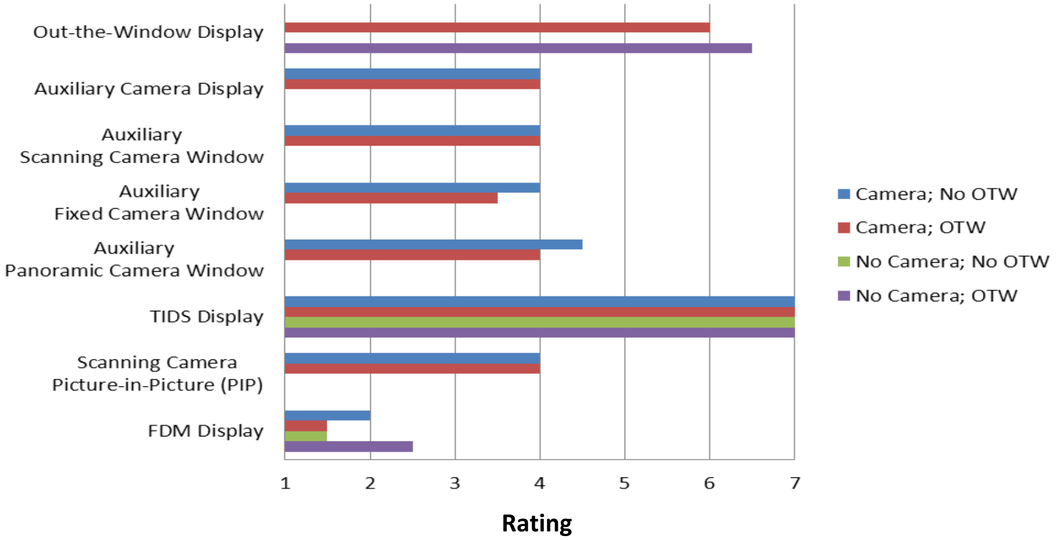

Figure 66. Median ratings for helping to maintain awareness of runway incursions by display or camera type.

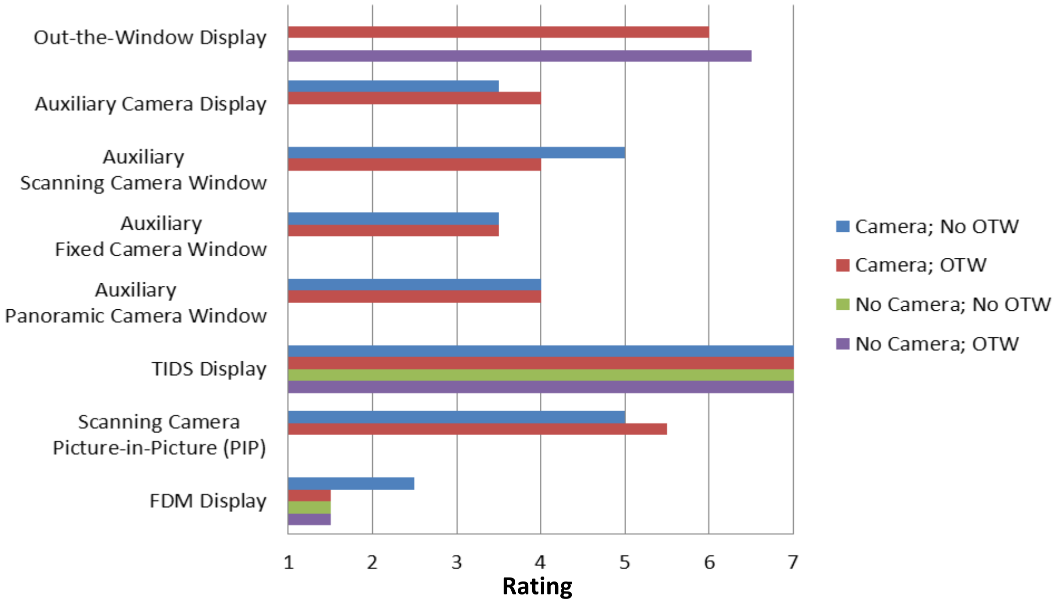

Figure 67. Median ratings for helping with off-nominal responses by display or camera type.

3.4.2. Feedback on camera placement

In the post-run questionnaires, the controllers were asked what locations or camera coverage they would most want to see displayed via the camera displays. Some of the locations that they suggested included the approach area, the departure end of runway, the run-up pad, the specific taxiways (K and EL), the intersections of the far runway (to help them determine whether an aircraft was clear of the runway), a separate view for all approach runways, and a greater coverage of the entire runway.

3.4.3. Feedback on camera use

In feedback provided on camera use, the controllers indicated that there were features that they would like to have available that were not available during SNT HITL 2. They reported that they would like to see call-signs depicted and would like to have pan, tilt, and zoom controls that were easier to use.

3.4.4. Feedback on FDM

For the FDM, although controllers generally were positive, they did have a few suggestions. They disliked the strip reposition feature and wanted the departure bay to consistently show the next aircraft ready for departure. Currently, the scroll bar moves to the middle of the list in the departure bay which hides the strips for the next departure. Sometimes, the controllers reported that strips would bounce back and when this occurred it would require too much of their attention. Additionally, the ground controller reported that they would like to be able to quick look the local controller's FDM.

3.4.5. Frequency of camera use

To better understand how frequently controllers were using the different camera components, they were asked to indicate on a scale of 1 to 7, with 1 indicating *very little* and 7 indicating *very much,* how much interaction they had with the auxiliary camera display, scanning camera window, fixed camera window, panoramic camera window on the auxiliary display, and PiP scanning camera inset on the TIDS (see Figure 68). The controllers gave the highest ratings to the PiP scanning camera and the panoramic camera window on the auxiliary display, which was consistent with their subjective feedback. Ratings for both of these were higher when there was no OTW view, again indicating their increased utility in the contingency configuration. However, using a Wilcoxon Signed Rank Test, we found that none of the differences in ratings between the Supplemental and Contingency conditions were significant.

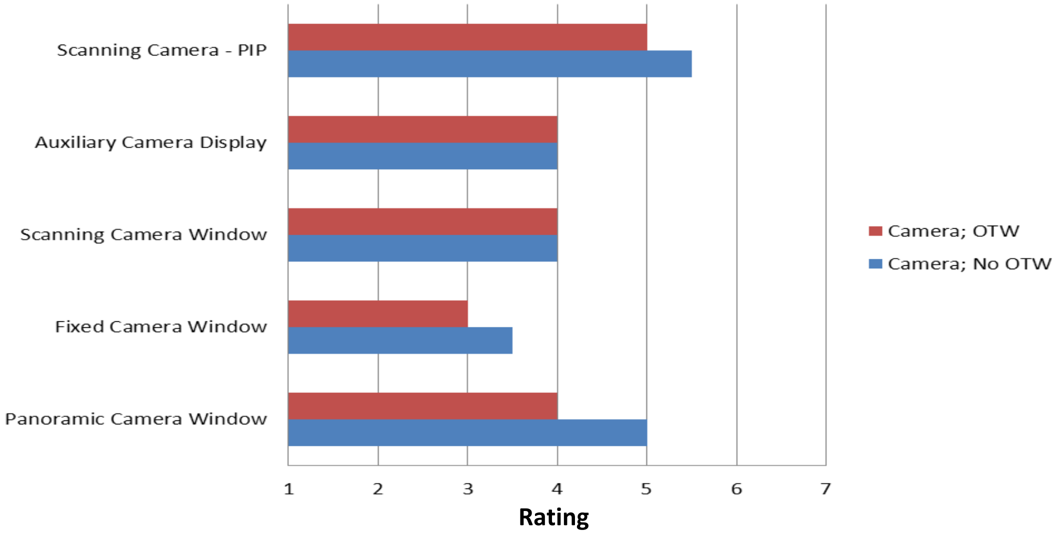

Figure 68. Median ratings on the amount of interaction with the camera windows both with and without the OTW view.

3.4.6. National Aeronautics and Space Administration-Task Load Index

Using the Friedman Test, we compared National Aeronautics and Space Administration-Task Load Index (NASA-TLX) ratings across conditions (see Figure 69). There were no significant differences across camera and SNT conditions for effort, performance, frustration, temporal demand, physical demand, or mental demand.

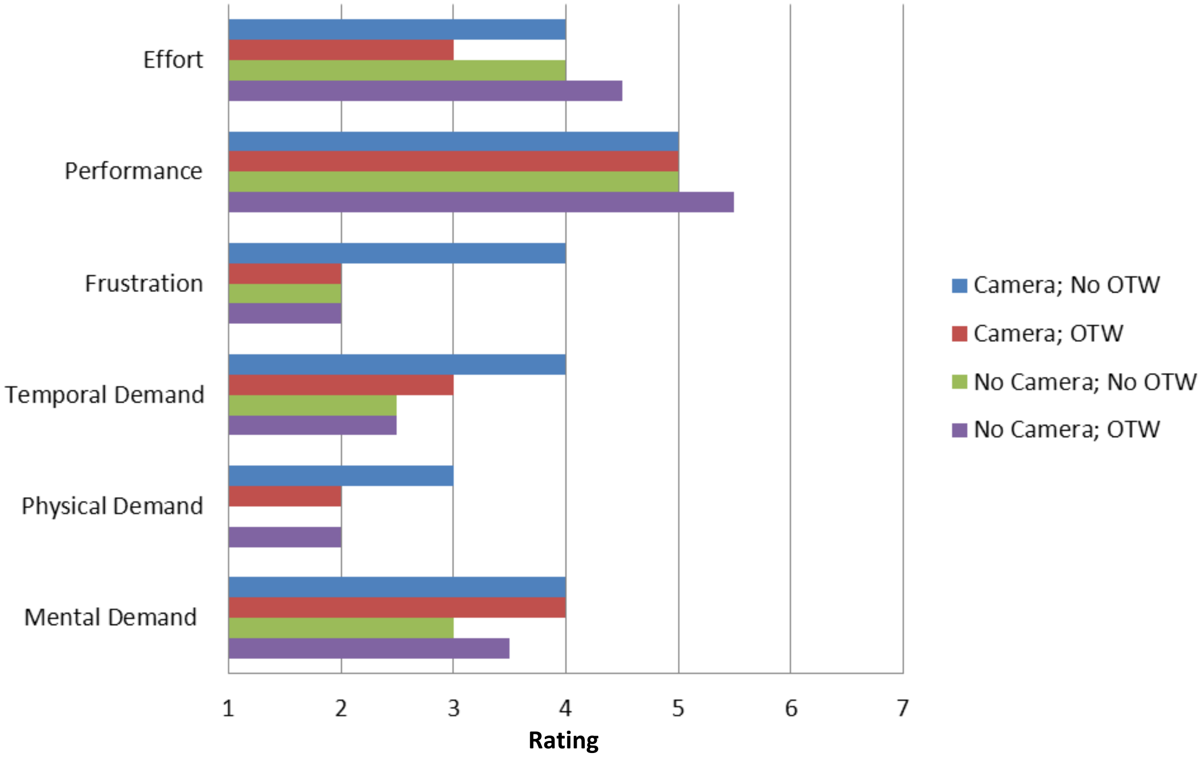

Figure 69. NASA-TLX ratings by condition.

3.4.7. Self-reported situation awareness

We also evaluated self-reported situation awareness overall and for a number of ATC and scenario-specific tasks (see Figure 70). For overall situation awareness, coordination between controllers, communications between controllers and pilots, and off-nominal events we compared ratings across all camera and SNT conditions. Using the Friedman Test, we found no significant differences across conditions for overall situation awareness, situation awareness related to coordination between controllers, situation awareness related to communications between controllers and pilots, and situation awareness related to off-nominal events. For situation awareness related to interactions with the camera (scanning PiP camera, scanning camera overall, fixed camera toggling, fixed camera window, and the panoramic camera window), we compared ratings for the conditions with cameras.

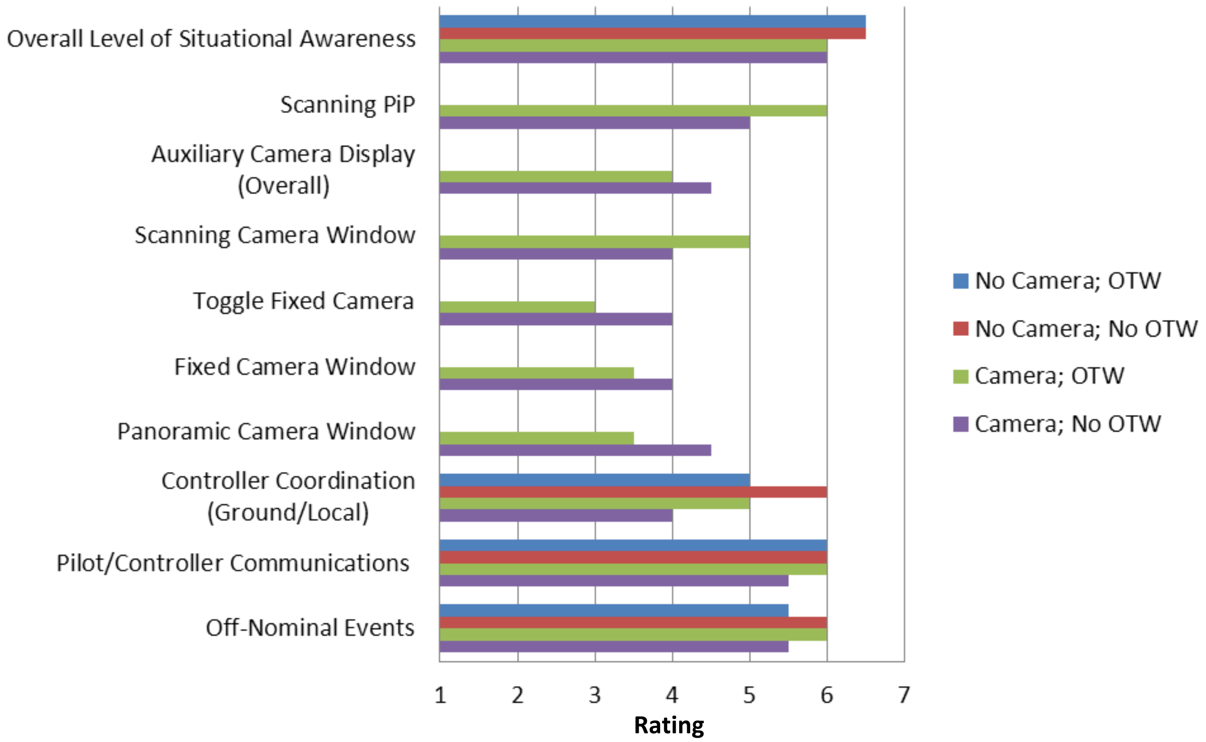

Figure 70. Median situation awareness ratings by condition.

3.5. Self-Reported Workload

As we did with situation awareness, we evaluated overall self-reported workload and workload for a number of ATC and scenario-specific tasks (see Figure 71). For overall workload, coordination between controllers, communications between controllers and pilots, and off-nominal events we compared ratings across all camera and SNT conditions. Using the Friedman Test, we found no significant differences across conditions for overall workload, workload related to coordination between controllers, workload related to communications between controllers and pilots, and workload related to off-nominal events. For workload related to interactions with the camera windows (scanning PiP camera, scanning camera overall, fixed camera toggling, fixed camera window, and the panoramic camera window), we compared ratings only for the conditions with cameras. None of these differences were significant.

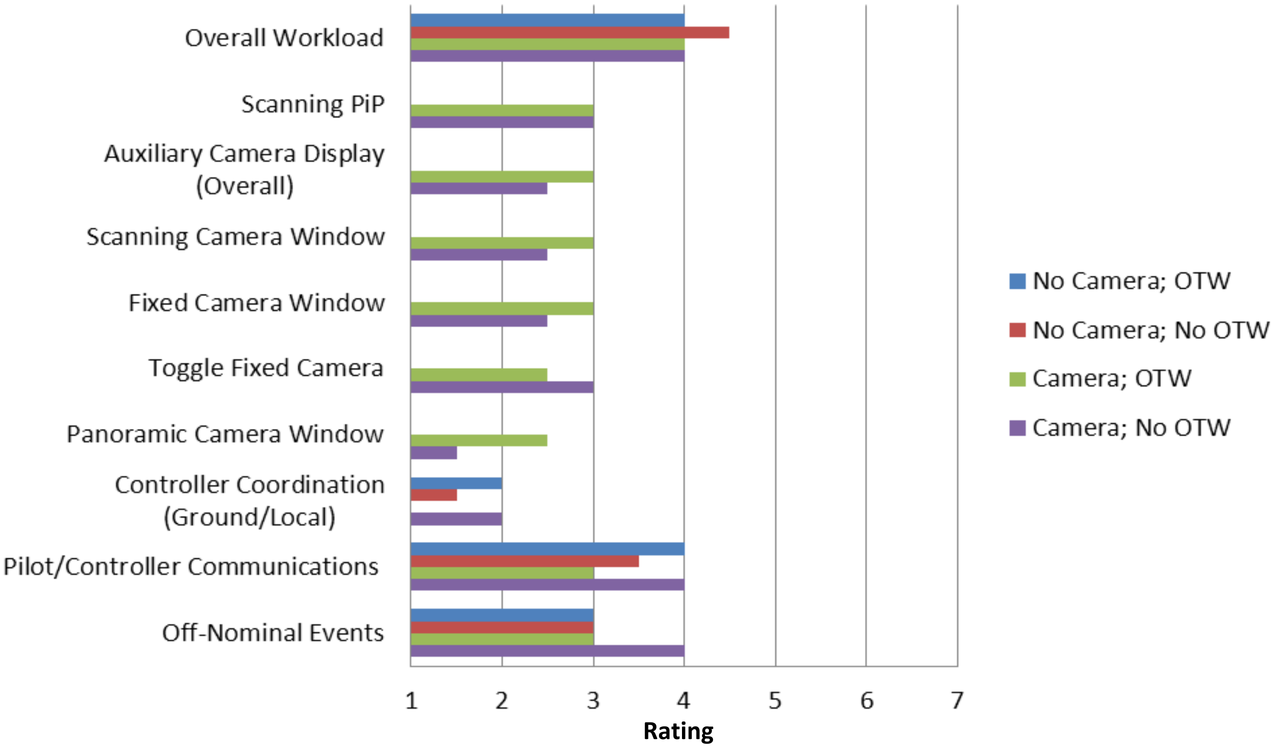

Figure 71. Median workload ratings by condition.

3.6. Post-Evaluation Questionnaire Data

3.6.1. Training ratings

Participants rated training effectiveness on a scale of 1 to 7, where 1 indicated *very ineffective* and 7 indicated *completely effective*. Although the participants rated the TIDS training very high, the training for the auxiliary camera was rated in the moderate range (see Figure 72). However, this was not surprising given that not much training was required for the auxiliary camera interface. For the fixed camera, the user could toggle through the four fixed camera images, but usually set the fixed camera to a single image and did not change it. For the scanning camera, most controllers used the PiP image, not the auxiliary image, and the rating for the PiP training was high. The panoramic camera view was static and, therefore, we did not provide training on its use.

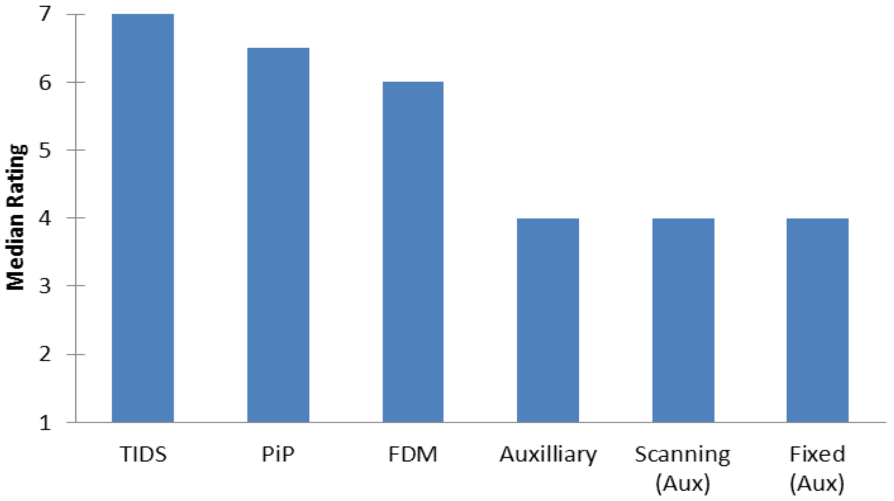

Figure 72. Training effectiveness ratings.

Participants also rated the realism of different aspects of the simulation on a scale of 1 to 7, where 1 indicated *not at all realistic* and 7 indicated *extremely realistic*. The median rating for the overall simulation realism was 4.5 and all of the other ratings were 4 or higher (see Figure 73). Participants cited various issues that detracted from the realism of the simulation. Aircraft in the simulation were not generated at the gate. In addition, the simulation pilots typically did not wait until the controllers contacted the aircraft at the spots as they do at DFW. One controller commented that they would prefer to have used the view from the east tower. Finally, although the aircraft models were fairly realistic, there are simulation limitations that can affect how the aircraft maneuver on the ground.

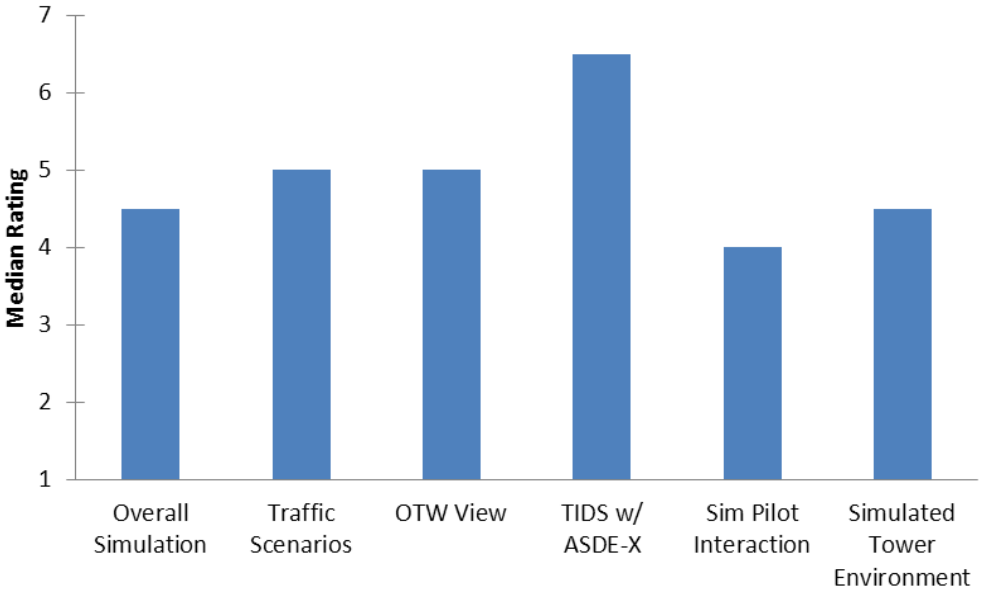

Figure 73. Median realism ratings.

Participants rated the degree to which the oculometer interfered with ATC performance, where 1 indicated *not at all* and 7 indicated *a great deal*. Ratings varied greatly (see Figure 74). However, it should be noted that even though all participants answered this question, only half of them were able to use the oculometer. Those individuals who required corrective lenses and who wore glasses rather than contact lenses could not use the oculometer because they could not be calibrated.

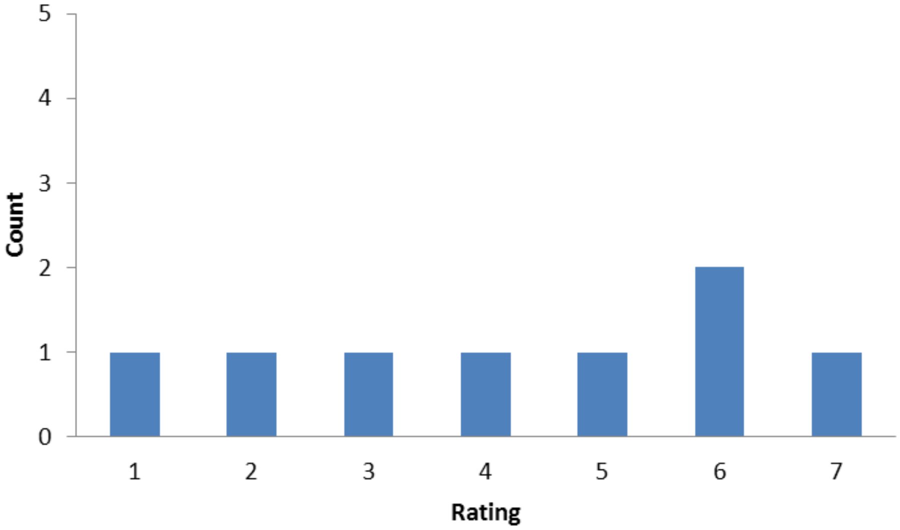

Figure 74. Frequency distribution of oculometer interference ratings.

Using a Friedman test, we evaluated whether controllers gave different rank-ordered preferences in their camera interaction task ease ratings (see Figure 75). For the pan, tilt, zoom, track a target, select a target, resize viewing area, and select viewing area functions, the controllers rated overall task ease and task ease with the two types of scanning cameras (auxiliary and PiP). There were no significant differences in the ratings for pan, tilt, zoom, track a target, select a target, or resize a viewing area. There was a significant difference for task ease ratings for selecting a viewing area, $\chi^2(2) = 9.29$, $p = .01$. Median ratings and the interquartile ranges for the ease with which controllers could select a viewing area overall, using the PiP or using the auxiliary camera were 4 (3 to 4.75), 6 (4 to 6), and 5 (4 to 6), respectively. For determining the aircraft type and for determining the aircraft location (see Figure 75), the controllers rated overall task ease and task ease with the two types of scanning cameras (auxiliary and PiP), the panoramic camera, and the fixed camera. There were no significant differences in the median ratings for determining aircraft location. There was, however, a significant difference in the ratings for determining aircraft type, $\chi^2(4) = 10.30$, $p = .04$. Median task ease ratings and the interquartile range for determining aircraft type overall, using the PiP scanning camera, the auxiliary scanning camera, the fixed camera, and the panoramic camera were 6.5 (4.25 to 7), 6 (4.25 to 7), 4 (4 to 5.75), 4.5 (4 to 6.75), and 5 (4 to 6.75), with the highest ratings being given to overall ratings and the PiP scanning camera.

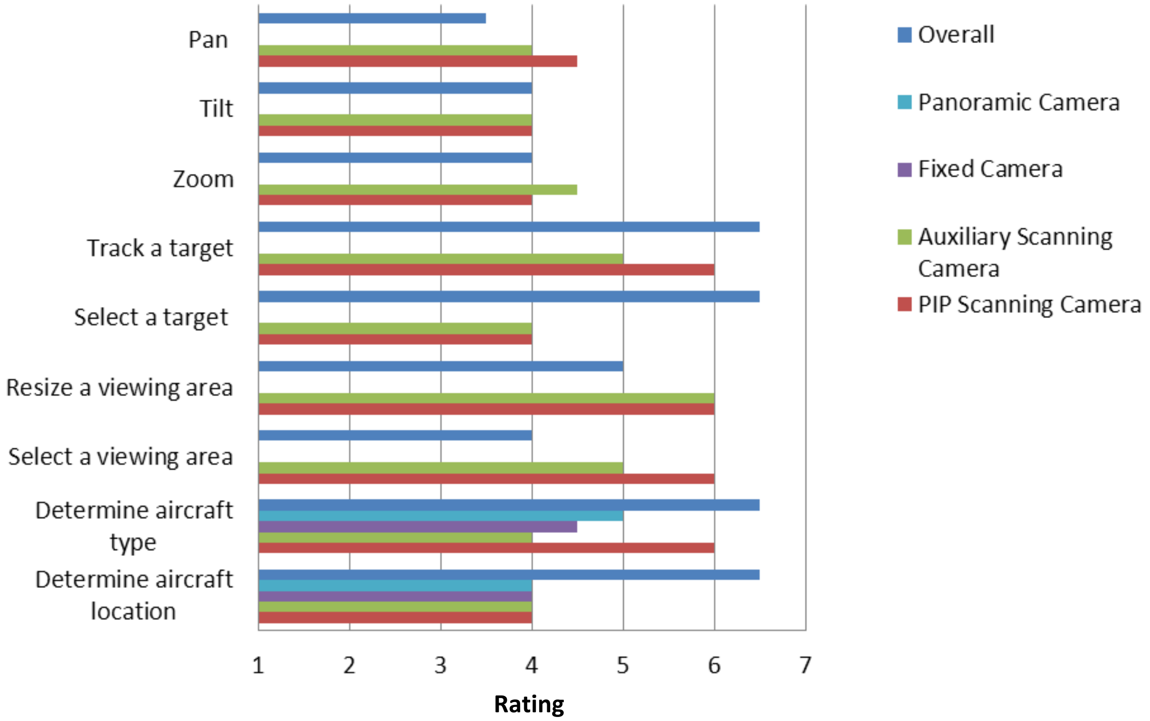

Figure 75. Median camera interaction task ease ratings overall and for different camera views.

The controllers rated the overall adequacy of different camera features and the camera images themselves (see Figure 76). For the scanning and target tracking features, the controllers reported overall adequacy, adequacy of the feature on the PiP scanning camera, and adequacy of the feature on the auxiliary scanning camera. There were no significant differences for the ratings of the scanning or the tracking feature, overall, on the PiP scanning camera, and on the auxiliary scanning camera. For aiding in nonconformance detection, the controller adequacy ratings were similar when comparing overall ratings, PiP scanning camera ratings, auxiliary scanning camera ratings, panoramic camera ratings, and fixed camera ratings. However, there was a significant difference in the ratings for aiding in the ability to maintain overall situation awareness, $\chi^2(4) = 10.22$, $p = .04$. For aiding in the ability to maintain overall situation awareness, the median controller adequacy ratings and interquartile ranges were 5.5 (4.25 to 6) overall, 4.5 (3.25 to 6.75) for the PiP scanning camera, 4 (3.25 to 5) for the auxiliary scanning camera, 5 (3.25 to 5) for the panoramic camera ratings, and 4 (3.25 to 5) for the fixed camera ratings.

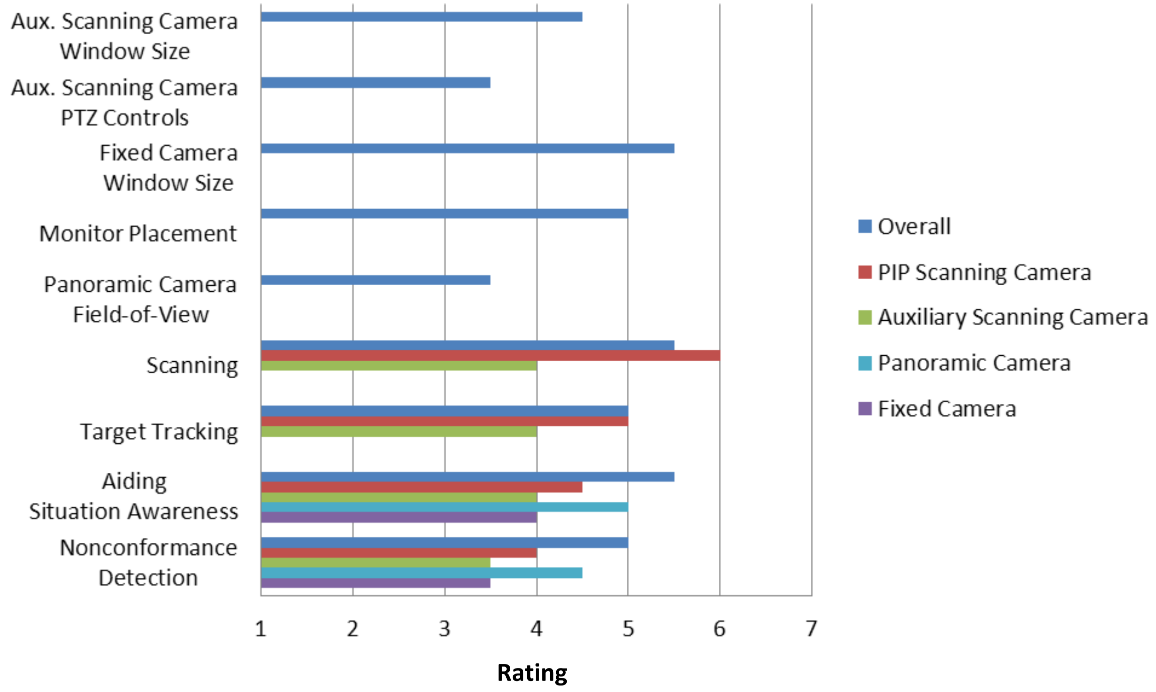

Figure 76. Median adequacy ratings overall and for different camera views.

The controllers rated the necessity of the cameras overall, for the PiP scanning camera, and for the auxiliary scanning camera to evaluate the benefit of cameras in both Contingency SNT and Supplemental SNT (see Figure 77). There were no significant differences in any of the ratings.

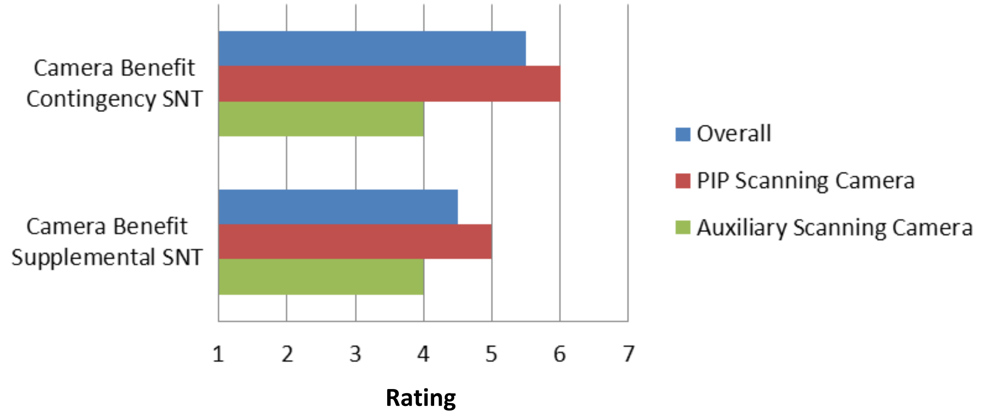

Figure 77. Median ratings for the necessity of cameras in Contingency and Supplemental SNT overall and for different scanning camera options.

We also evaluated the controller ratings for the acceptability of camera features, including the off-nominal alerting capability, the overall presentation, the camera resolution, the camera functionality, and the lag time related to camera responsiveness (see Figure 78). For each of these features, the controllers gave an overall rating, a PiP scanning camera rating, and an auxiliary scanning camera rating. The only significant difference in ratings was for the off-nominal alerts, $\chi^2(2) = 6.5$, $p = .04$. For the off-nominal alerting capability, the median controller ratings and interquartile ranges were 6 (4 to 7) overall, 5.5 (4 to 7) for the PiP scanning camera, and 4.5 (3.25 to 6) for the auxiliary scanning camera.

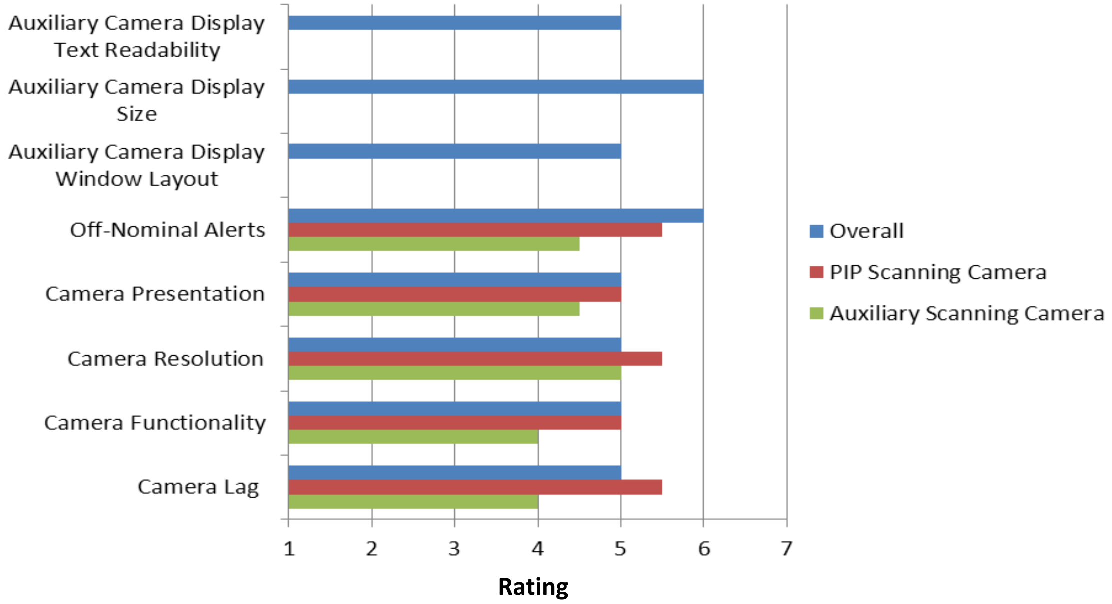

Figure 78. Median ratings for the acceptability of camera features for different scanning camera options.

Using the Wilcoxon Signed Rank Test, we compared ratings for Supplemental SNT and Contingency SNT for how essential different camera views would be for the controllers (see Figure 79). There were no significant differences between the ratings in the Supplemental and Contingency SNT conditions for ratings of controller-selected areas, areas or aircraft under alert, blocked line-of-sight areas, runways and intersections, the approach area, and the panoramic airport view, indicating that controllers found them equally essential in both SNT conditions.

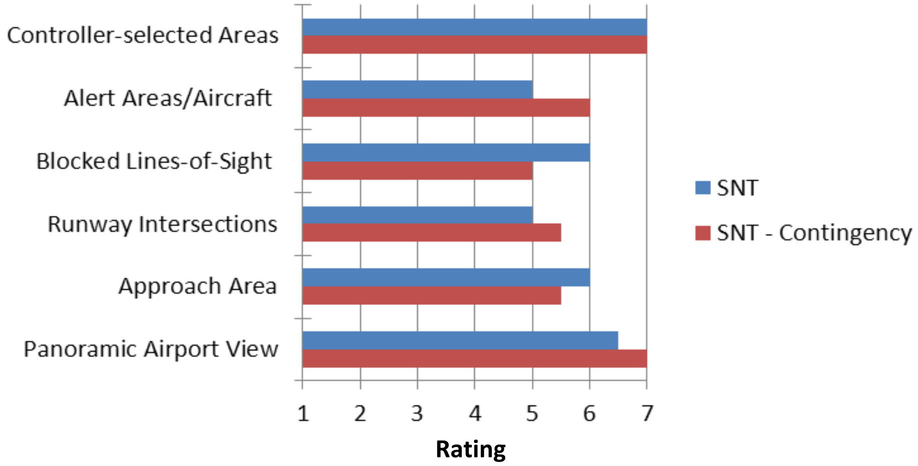

Figure 79. Median ratings for how essential different camera views are in both Supplemental and Contingency SNT.

The controllers were also asked to provide ratings as to whether or not they believed SNT would provide a benefit to the NAS or to tower controllers in either Contingency or Supplemental SNT (see Figure 80). There were no differences in ratings for the benefits to the NAS or tower controllers and no differences in ratings for either Contingency or Supplemental SNT. Overall, the ratings were higher for Supplemental SNT but were also fairly high for Contingency SNT, validating the potential usefulness of Contingency SNT concept.

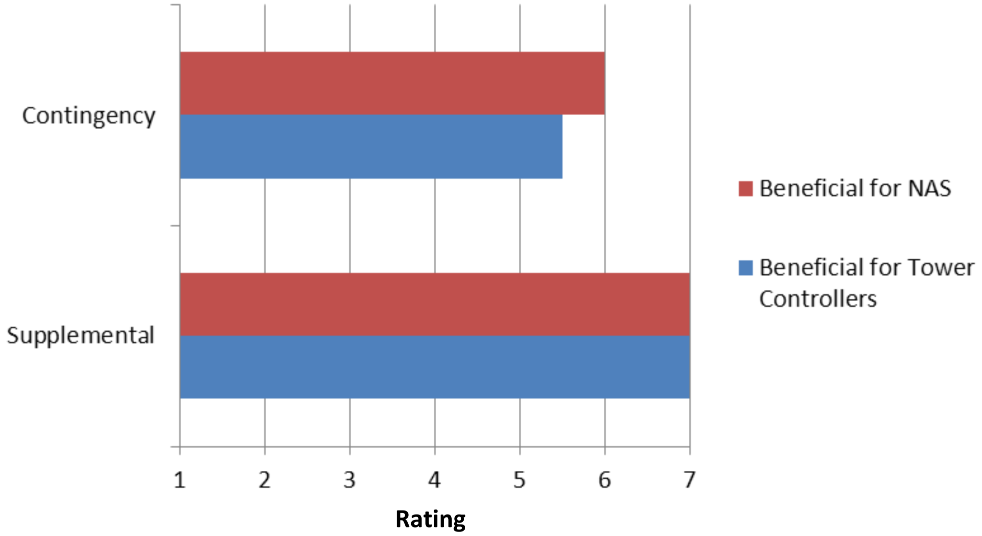

Figure 80. Median ratings for the benefit provided by SNT to the NAS and to tower controllers in both Supplemental and Contingency SNT.

We also collected feedback on ease of use ratings for performing essential tasks on the TIDS (see Figure 81), adequacy ratings for TIDS display features (see Figure 82), ease of use ratings for performing essential tasks on the FDM (see Figure 83), and adequacy ratings for FDM display features (see Figure 84). On the whole, ratings for the TIDS for performing essential tasks were fairly high, with most ratings being 5 or higher. They did give somewhat lower median ratings for maintaining data block separation (3.5), moving a data block (4), and finding flight information (4). All of the ratings for the adequacy ratings for TIDS display features were high, with all median ratings being greater than 6. The ratings for the FDM for performing essential tasks and for the adequacy of FDM display features were fairly high, as well, with all ratings being 5 or higher. We also asked the controllers which would they rather give up, the TIDS or the OTW view. Half of the controllers indicated that they would rather give up the TIDS, whereas the other half of the controllers indicated that they would rather give up the OTW view.

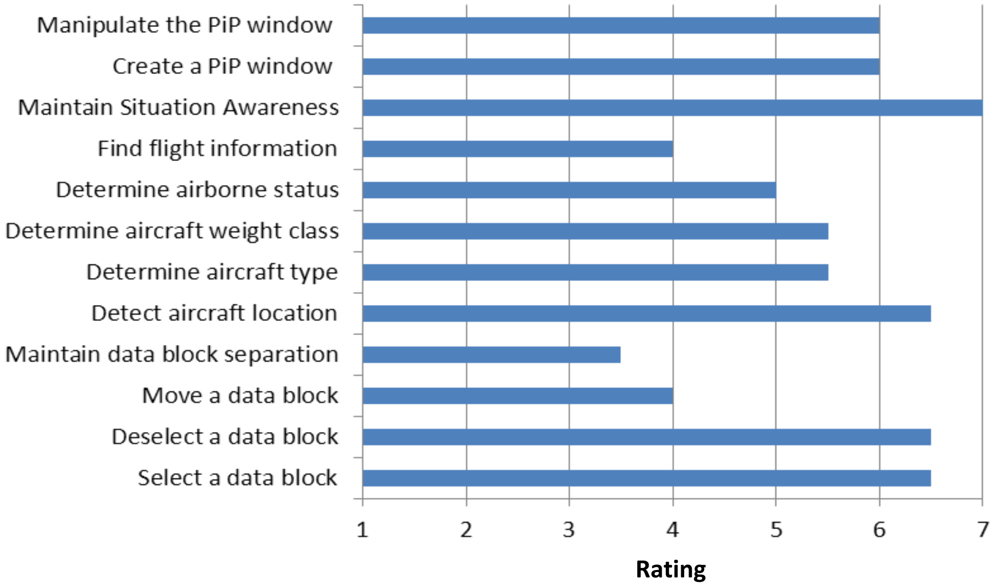

Figure 81. Median ease of use ratings for performing essential tasks on the TIDS.

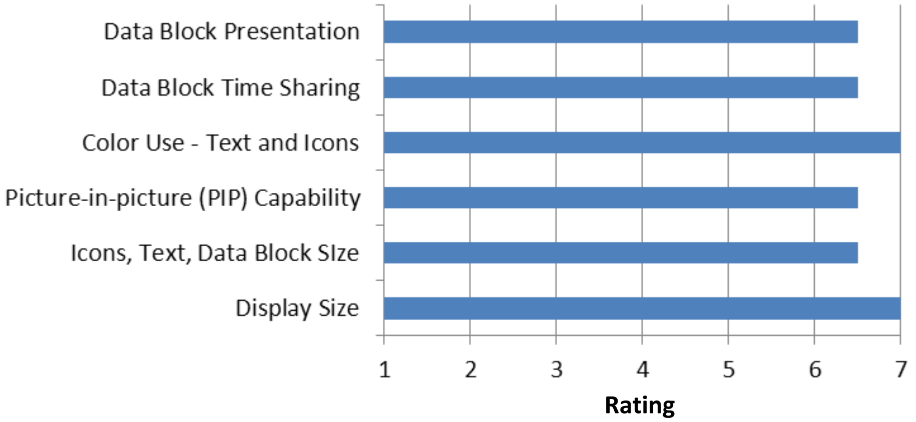

Figure 82. Median adequacy ratings for TIDS display features.

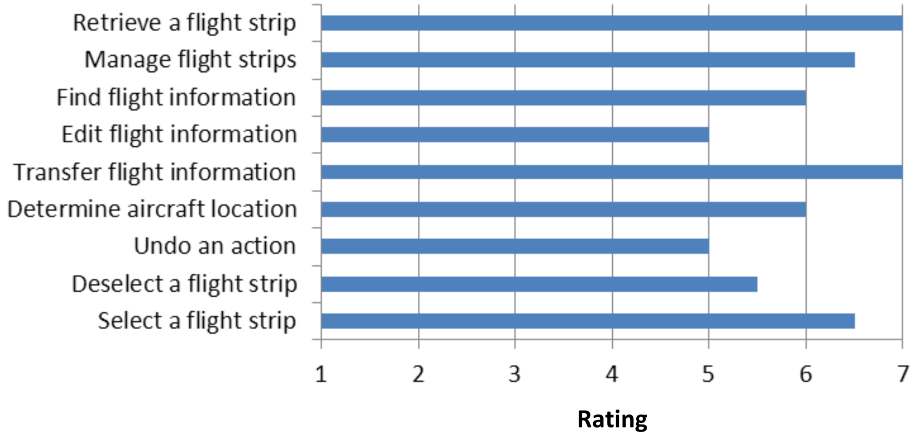

Figure 83. Median ease of use ratings for performing essential tasks on the FDM.

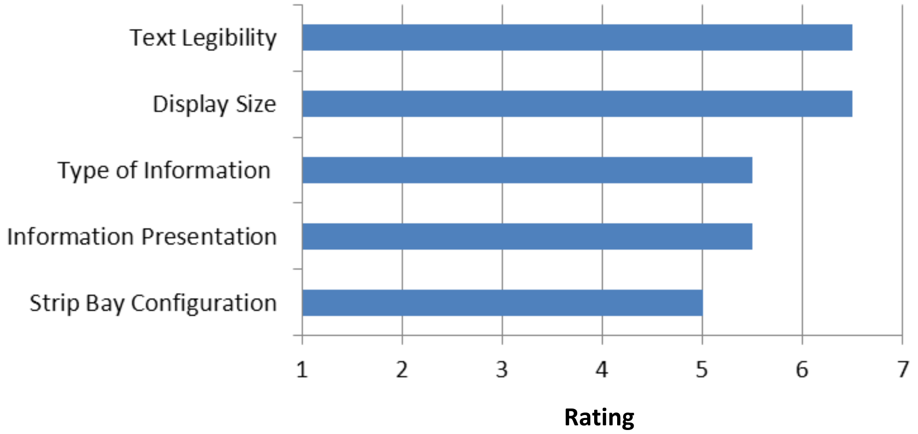

Figure 84. Median adequacy ratings for FDM display features.

4. CONCLUSION

Results of this study show that controllers can perform their jobs effectively in both Supplemental and Contingency SNT environments. Although the controllers felt the cameras were less critical or important in the Supplemental condition, the controllers rated the camera to be essential in both conditions. They also believed that the SNT concept would be beneficial for the NAS and for control tower operations.

4.1. Supplemental and Contingency Comparison

One of the objectives of this study was to determine whether the cameras would provide a benefit to controllers in the event of an off-nominal event. Without an OTW view, such as in a Contingency SNT environment, there would be a need to meet information requirements via some other means, either with a situation display, such as the TIDS, or potentially through the use of a camera view display. We wanted to determine whether the cameras would provide the controllers with an adequate means of detection, whether there was a need to implement some type of alerting logic to cue controller attention to any unexpected events, and whether there were additional CHI considerations.

Of the four planned off-nominal events in this study, only one was detected via camera views with any consistency. In the camera condition, the primary means of detection was via the PiP only for the gear up off-nominal event. However, it is interesting to note that the controllers did not detect this event at all via the OTW display, and they did not have the opportunity to detect it when there was no visual display. It is possible that the nondetection when the controllers only had the OTW view may have been due to limitations of the simulation environment, but in field demonstrations at DFW, researchers also found that detection of a wheels up off-nominal event was difficult and often did not happen without the presence of the camera image. Although there was no alerting logic for this event, the controllers were able to detect it fairly consistently via the PiP camera display. It should be noted that the cameras were set to track the arrivals, which meant that the aircraft with the gear up was typically the object of focus for the PiP. Therefore, if there were a desire to use cameras for gear-up detection, it would be critical to set up any such camera system to track arrivals.

For the other off-nominal events, we did not find significant results. For the aircraft crossing an unoccupied runway event and the aircraft stopped on the runway event, they were generally detected via the TIDS or via the audible alerts and not by means of any of the camera views. It is interesting to note that in the case of the aircraft crossing an unoccupied runway when there was no alerting available, the controllers successfully identified aircraft nonconformance using just the TIDS, which is an indication that the controllers did not need cameras or alerts to detect this off-nominal event. However, when alerting was available, the means of detection were split between the TIDS and the alerts. This is an indication that the controllers utilized the alerts when they were available and that the alerts were beneficial and helped to draw controller attention to the off-nominal situation. The controllers did indicate in their subjective feedback that they did like the alerts as long as the algorithms could accurately detect off-nominal events. It would be interesting to evaluate the eye-movement data to determine whether the alerts trigged a controller saccade to the camera PiP window. We plan on performing this analysis in a future deep-dive exploration of the eye-movement data.

While the overall PTT results were not significant, the local controller results differed somewhat from the ground controller results. The average PTT duration for the ground controllers was marginally longer in the Contingency SNT condition. For the local controller, however, there was a significant interaction between the SNT condition and the availability of the camera. The local controllers in the Supplemental condition with no cameras present had longer communications than in the Contingency SNT condition. However in the Contingency condition with cameras present, the local controllers had longer communications than in the Supplemental condition. It appears that there may have been a minor shift in the control style employed by the local controllers that was contingent upon the availability of cameras and an OTW view.

For the most part, there were no significant results for the ground-based performance metrics. However, when controllers had access to cameras, the distance between departures was greater in the Supplemental condition, but when they had no cameras the distance between departures was greater in the Contingency condition. Although it is difficult to explain why the departures were spaced more with cameras and with the OTW present, we believe that it is possible that the absence of both cameras and an OTW view led the controllers to be more conservative with departure spacing.

The eye-tracker data provided us with a greater insight into where controller attention was directed as well as some indication of workload. For the Supplemental condition, the local controllers spent more time fixating on the TIDS when cameras were present, but more time fixating on the TIDS in the Contingency condition when no cameras were present. Obviously, in the Contingency environment, there were fewer displays to divide the controllers' attention. In the Supplemental environment, the PiP could be set to track the arrivals. As a result, there was less of a need to look at the external camera monitor. Without the camera, it was logical that the controllers would use the OTW to check the visual scene in lieu of using the PiP.

For the local controller in the Supplemental condition, there were a higher average number of saccades on the TIDS when the cameras were present, but in the Contingency condition there were a higher average number of saccades on the TIDS when there were no cameras present. These results were consistent with the fixation results. For the ground controller, there was little difference in the proportion of fixations on the TIDS display in either camera condition. However, when there were no cameras, there were a higher proportion of fixations on the TIDS display in the Contingency condition. This makes sense, because without an OTW view, the only thing the controllers can rely on is their primary situation display, which in this study was the TIDS. The ground controller also seemed to utilize the cameras differently than the local controller. However, we believe that the camera views for the local controller may have been configured more optimally than the camera views for the ground controller—and, if alternative ground control views were identified, we might expect to see a pattern of results more similar to the local controllers.

For the Contingency condition, we found saccade distances were shorter, indicating higher workload, for the ground controllers. For the ground controller, there were marginally more average fixations on TIDS and less average fixations on the FDM. There was also a higher proportion of fixations on the TIDS when no cameras were present and a higher proportion of saccades on the TIDS. Conversely, there were a smaller proportion of saccades on the TIDS for the local controllers when a camera was present. Again, this is logical because with no cameras, the controllers have fewer displays to look at so they focus more on the TIDS.

4.2. Camera and No Camera Condition Comparison

In the Camera condition, there was a marginally higher number of saccades and shorter blinks, indicating increased workload for the ground controller. Conversely, when the controllers worked as the local controller, on average, they had smaller pupil diameters, which is an indication of lower workload. These results were consistent with the other eye-movement data. Additionally, the eye-movement data were all consistent with the local controllers being more likely to use the TIDS or the PiP to perform their tasks, and with the ground controllers being more likely to us the OTW to maintain their situation awareness.

4.3. Questionnaire Summary

In general, median ratings for the TIDS were higher than the median ratings for the OTW, and the median ratings for the TIDS were highest for detecting off-nominal events. Although lower than the TIDS ratings, the median OTW ratings were also consistently high, with all questions receiving median ratings of 6 and above. Ratings of maintaining safe operations in the No Camera condition were the exception for the OTW, with a median rating of 7. This conveys the controllers' opinions that some type of visual of the operational environment is necessary for them to perform their tasks adequately.

The cameras and the FDM were both rated lower than the TIDS and the OTW, especially in the Supplemental condition. The ratings for the auxiliary scanning camera were sometimes lower than for the PiP scanning camera. In this study, the controllers found it more useful to have the scanning camera window directly on the TIDS display, which contradicts the findings in SNT HITL 1.5 (Friedman-Berg et al., 2012). We attribute this difference to technical improvements and changes in the CHI, such as the implementation of an intelligent logic that was used to drive the scanning camera to events and AOIs to the controller. Ratings for the camera and its various inset windows were higher when there was no OTW view. This was likely because in Supplemental SNT, the windows provide the controllers with their primary view of the operational environment. Therefore, the camera views in Supplemental SNT were less critical for maintaining situation awareness.

This study met its primary objective of determining whether cameras were beneficial for SNT operations in either the Supplemental or Contingency environment. We believe that based on this study and on the objective and subjective metrics, the cameras importance to the SNT concept has been demonstrated and merits future exploration to refine and expand these findings. The feedback we received from the controllers regarding camera coverage, display configuration, and control functionality will guide our development for future efforts. For example, the controllers specifically recommended providing a separate view of each arrival runway, along with views of critical intersections. Although some recommendations may have been specific to DFW, other airports likely have similar issues and would benefit from addressing these issues. We also plan to continue to improve the CHI based on the feedback provide by the controllers. One high-priority issue that we plan to address in future HITLs is including call-signs on the camera views to allow the controllers to correlate the aircraft in the camera images with the aircraft targets on the TIDS. We believe this small improvement should lead to better situation awareness and better ATC performance.

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References

Ahlstrom, U., & Friedman-Berg, F. (2005). *Subjective workload ratings and eye movement activity measures* (DOT/FAA/CT-05/32). Atlantic City International Airport, NJ: Federal Aviation Administration William J. Hughes Technical Center.

Engelland, S. A., & Ruszkowski, L. M. (2010, September). Analysis of DFW Perimeter Taxiway Operations. In the *10th AIAA Aviation Technology, Integration, and Operations (ATIO) Conference*. Fort Worth, TX.

Federal Aviation Administration. (2011a). *Field demonstration #2 final report for Staffed NextGen Tower (SNT)*. Washington, DC: Author.

Federal Aviation Administration. (2011b). *Field demonstration #2 final report for Tower Flight Data Manager (TFDM)*. Washington, DC: Author.

Friedman-Berg, F. J., Racine, N., Jones, S., & Baptiste, M. (2012). *Staffed NextGen Tower: Part-task camera integration computer-human interface evaluation*. Atlantic City International Airport, NJ: Federal Aviation Administration William J. Hughes Technical Center. Manuscript in preparation.

George Mason University. (2009). *Staffed NextGen Tower Walkthrough*. Fairfax, VA.

Hannon, D. J. (2009). *Staffed NextGen Tower (SNT) Quick Look Study*. Cambridge, MA: U.S. Volpe National Transportation Systems Center.

Hannon, D. J., Lee, J., Geyer, M., Mackey, S., Sheridan, D., Francis, M., …Malonson, M. (2008, Winter). Feasibility Evaluation of a Staffed Virtual Tower. *The Journal of Air Traffic Control,* 27−39.

Hannon, D. J., Lee, J., Sheridan, T. B., & Donohoe, C. (2008). Tower Information Display System human-in-the-loop simulation and evaluation. In *Proceedings of the 8th Integrated Communications, Navigation, and Surveillance Conference*, Bethesda, MD.

Iqbal, S. T., Adamczyk, P. D., Zheng, X. S., & Bailey, B. P. (2004). Changes in mental workload during task execution. In *Proceedings of the 17th Annual ACM Symposium on User Interface Software and Technology,* Santa Fe, NM. Retrieved from http://orchid.cs.uiuc.edu/publications/UISTshort.pdf

Iqbal, S. T., Zheng, X. S., & Bailey, B. P. (2004). Task-evoked pupillary response to mental workload in human-computer interaction. In *Proceedings of the 2004 Conference on Human Factors in Computing Systems* (*CHI 2004)*, Vienna, Austria. Retrieved from http://orchid.cs.uiuc.edu/publications/ acm-chi-2004-iqbal.pdf

Nene, V. (2011). *On the use of digital camera(s) in an SNT environment.* MITRE Corporation, McLean, VA.

Nickleson, M., Jones, S., & Zimmerman, T. (2011). *Staffed NextGen Tower human-in-the-loop simulation 1.0: Draft final report.* Federal Aviation Administration William J. Hughes Technical Center.

Van Orden, K. F., Limbert, W., Makeig, S., & Jung, T. P. (2001). Eye activity correlates of workload during a visuospatial memory task. *Human Factors*, *43*(1), 111−121.

Zeghal, K., Grimaud, I., Hoffman, E., & Rognin, L. (2002). Delegation of spacing tasks from controllers to flight crew. Impact of controller monitoring tasks. In *Proceedings of the IEEE/AIAA Digital Avionics Systems Conference*, Irvine, CA.

Acronyms

AOI	Area of Interest
ASDE-X	Airport Surface Detection Equipment-Model X
ATC	Air Traffic Control
CARTS	Common Automated Radar Terminal System
CHI	Computer-Human Interaction
DESIREE	Distributed Environment for Simulation, Rapid Engineering, and Experimentation
DFW	Dallas Fort-Worth International Airport
DPS	Department of Public Safety
FAA	Federal Aviation Administration
FLM	Front Line Manager
FDM	Flight Data Manager
HFE	Human Factors Engineer
HITL	Human-In-The Loop
IG	Image Generator
MIT LL	Massachusetts Institute of Technology Lincoln Laboratory
NAS	National Airspace System
NASA-TLX	National Aeronautics and Space Administration-Task Load Index
NextGen	Next Generation Air Transportation System
NIEC	NextGen Integration and Evaluation Capability
OTW	Out-The-Window
PI	Principal Investigator
PiP	Picture-In-Picture
PTT	Push-To-Talk
RACD	Remote ARTS Color Display
SimPilot	Simulation Pilot
SME	Subject Matter Expert
SNT	Staffed NextGen Tower
SOP	Standard Operating Procedure
STARS	Standard Terminal Automation Replacement System
TFDM	Terminal Flight Data Manager
TGF	Target Generation Facility
TIDS	Tower Information Display System
VESA	Video Electronics Standards Association
VFR	Visual Flight Rules
WJHTC	William J. Hughes Technical Center

Appendix A: Observer Off-Nominal Event Over-the-Shoulder Form

Observer Off-Nominal Event Over-the-Shoulder Form

OFF-NOMINAL EVENT: LOCAL 1 **TIME OF EVENT**__________

SCENARIO RUN ID ____

DESCRIPTION Aircraft Enters Active Runway - Occupied.

---

1 PLEASE CHECK ONE

- ☐ Completely unobserved
- ☐ Observed but no action taken
- ☐ Action taken at 1st opportunity…………….. ☐ succeeded ☐ failed
- ☐ Action taken at 2nd opportunity point…… ☐ succeeded ☐ failed

		PLEASE CIRCLE ONE				
2	RECOGNITION TIME The amount of time taken to recognize the event	1 Very inadequate	3 Neutral	5 Very adequate	N/A	
3	APPROPRIATENESS OF ACTION The appropriateness of the actions taken to resolve the event	1 Very inappropriate	3 Neutral	5 Very appropriate	N/A	
4	MEANS OF DETECTION	TIDS	CAMERA	OTW	FDM	OTHER
5	MEANS OF VERIFICATION From what display, if any, did the controller seek secondary or additional information?	TIDS	CAMERA	OTW	FDM	OTHER
6	OVERALL RATING The overall adequacy of the response to the event	1 Very inadequate	3 Neural	5 Very adequate	N/A	

*potential event and actual event used interchangeably

7 COMMENTS

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____
____
____

Appendix B: Camera Coverage Area

Camera Coverage Area

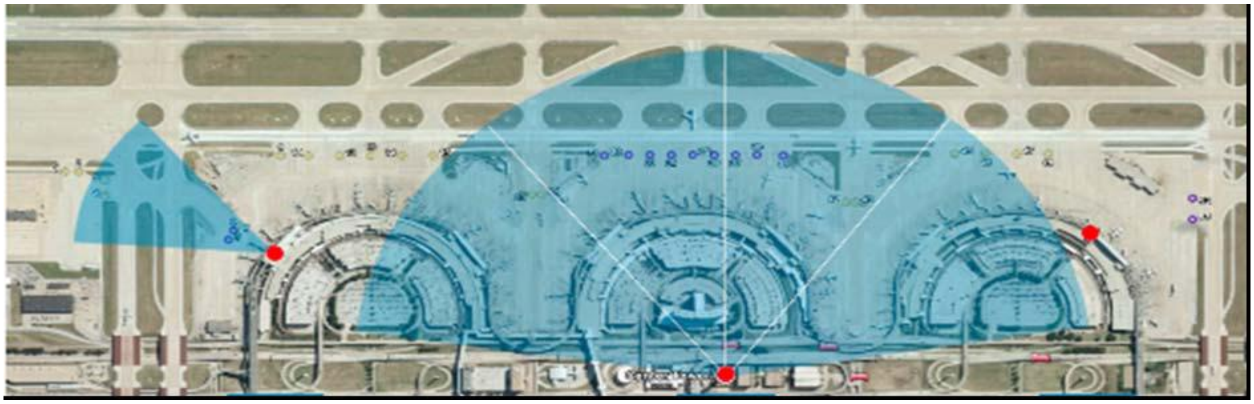


Figure. Coverage and viewing areas from Center Control Tower fixed camera placement. Graphic from MIT LL DFW coordination slide presentation.

Appendix C: Informed Consent Form

Informed Consent Form

Individual's Consent to Voluntary Participation in a Research Project

I, ______________________________, understand that this study, Staffed NextGen Tower Camera Integration Human-in-the-Loop 2, is sponsored by the Federal Aviation Administration (AJP-66, Concept Development and Validation) and is being directed by Ferne Friedman-Berg, Ph.D. (AJP-6110).

Purpose

As part of the Next Generation Air Transportation System (NextGen), the FAA envisions a paradigm shift in which tower services may be provided primarily via surface surveillance information on an integrated display. The purpose of this study is to investigate the effect a NextGen Tower environment may have on air traffic control (ATC) operations.

Procedures

I, along with a second controller, will serve as Ground and Local Controllers and perform routine ATC operations in a simulation environment. Simulated air traffic will be presented on a virtual out-the-window (OTW) tower display and/or a camera monitor display, STARS, and an integrated surveillance display (TIDS). Additionally an electronic flight data management (FDM) and a camera display will be used. I will be trained on how to use any unfamiliar technologies or tools and will be given practice sessions to ensure that I am comfortable with the systems. Once the practice sessions are completed, I will participate in eight experimental trials and four exploratory data collection trials. I understand that data may be recorded (video, audio, and simulation metrics). Additionally, I will fill out questionnaires and will provide subjective feedback. The experimental activities will occur over three consecutive days (Tuesday-Thursday).

Discomfort and Risks

The only foreseeable risk could be fatigue from the simulations.

Benefits

I understand that there are no monetary benefits to my participation. The only benefit is the opportunity to help the FAA assess the feasibility of the Staffed NextGen Tower concept.

Controller Responsibilities

During the research study, I will be at the WJHTC from 8:30am to 4:30pm each day.

Compensation and Injury

I will report any accident, injury, or illness immediately to Ferne Friedman-Berg, Ph.D. at 609-485-7460.

Controller’s Assurances

I understand that my participation in this study is completely voluntary. Dr. Friedman-Berg has adequately answered any and all questions I have about this study, my participation, and the procedures involved. I understand that Dr. Friedman-Berg will be available to answer any questions concerning procedures throughout this study. I understand that if new findings develop during the course of this research that may relate to my decision to continue participation, I will be informed.

I have not given up any of my legal rights or released any individual or institution from liability for negligence.

I understand that records of this study will be kept confidential and that I will not be identified by name or description in any reports or publications. All audio and video recorded during the study will be used only for this study and will remain secure.

I understand that I may withdraw from this study at any time without penalty or loss of benefits to which I am otherwise entitled. I also understand that the researcher of this study may terminate my participation if she feels this to be in my best interest or the best interest of the study.

If I have questions about this study or need to report any adverse effects from the research procedures, I will contact Ferne Friedman-Berg at 609-485-7460.

I have read this consent document. I understand its contents, and I freely consent to participate in this study under the conditions described. I have received a copy of this consent form.

*Research Controller:*____*Date:*________

*Investigator:*____*Date:*________

*Witness:*____*Date:*________

Appendix D: Biographical Questionnaire

Biographical Questionnaire

Controller # ____ Date _____

Instructions: This questionnaire is designed to obtain information about your background and experience as a certified professional controller (CPC). Researchers will only use this information to describe the controllers in this study as a group. Your identity will remain anonymous.

Demographic Information and Experience

1. Will you be **wearing corrective lenses** during this study?	○ Yes	○ No
2. What is your **age**?	_______ years	
3. How long have you worked as a **Certified Professional Controller (incl. both FAA and military experience)**?	_______ years _______ months	
4. How long have you worked as a **CPC for the FAA**?	_______ years _______ months	
5. How long have you **actively controlled traffic** in an airport traffic control tower**?**		
6. How many of the **past 12 months** have you actively controlled traffic in an airport traffic control tower?	_______ months	
7. Have you participated in any previous Staffed NextGen Tower evaluations?	○ Yes	○ No
If yes, please specify:		

8. Do you have operational experience with any electronic flight strip systems?		
		Years Exp
a. Advanced Electronic Flight Strip System (ORD)	○ Yes ○ No	
b. Electronic Flight Strip Transfer System (EFSTS)	○ Yes ○ No	
c. Other	○ Yes ○ No	
If yes, please specify:		

Appendix E: System Functionality Training

System Functionality Training

The intent of this SOP is to provide only the information relevant to this simulation. Unless otherwise specified, existing ATC procedures outlined in national or DFW directives (e.g. 7110.65, local SOPs and Letters of Agreement) are assumed to apply. Therefore, this document does not contain a full set of operating procedures that would be sufficient to conduct live air traffic operations in the field at DFW or any other airport.

There are two operational positions in this tower simulation. Local Control and Ground Control. Local Control (LC) and Ground Control (GC) require duty familiarization at the beginning of each scenario. A position relief briefing will be provided at the beginning of each shift and whenever a controller change is necessary.

Both LC and GC are responsible for the following:

- Issue appropriate control instructions to achieve and ensure arrival, departure, and runway separation
- Monitor and manipulate long range scanning camera controls
- Issue appropriate alerts or instructions when observed or prompted by safety logic
- Monitor and operate communications equipment
- Utilize tower traffic situation displays
- Visually scan airport environment
- Ensure electronic strip marking and posting is completed as required

At the start of each scenario, a position relief briefing will be provided by an Air Traffic Control Specialist. The briefing will contain the following information:

- Weather
- Equipment (including Certified/Uncertified status)
- Airport conditions/closures
- Runway status
- Traffic
    - Holding
    - Standing by
    - Coordination
    - Status of all display targets

Electronic departure flight progress strips will be provided, depicting flight data on active flights operating on the east side of DFW airport. These flight progress strips will be displayed on the GC and LC Flight Data Manager (FDM).

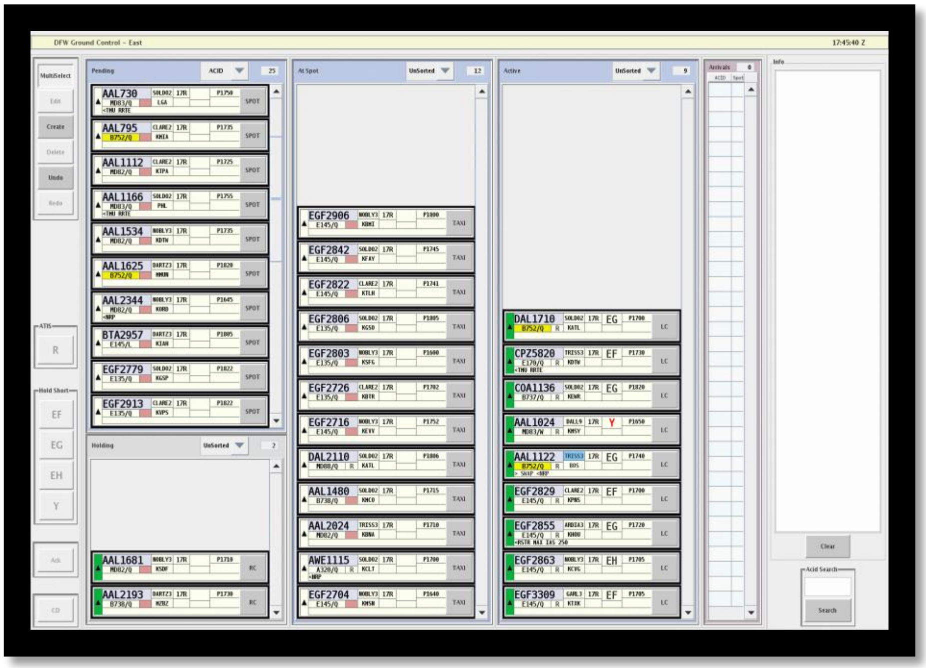
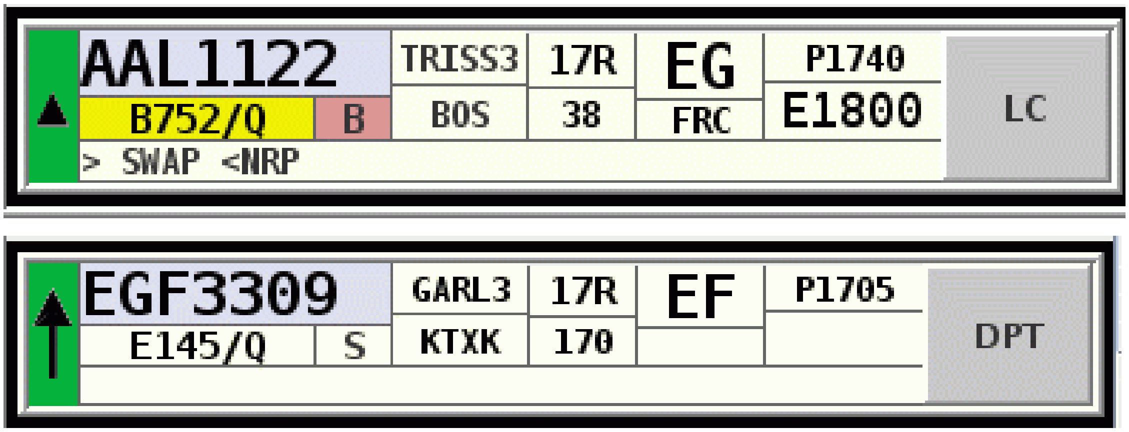


Figure E1. FDM Display.

All flight progress strip marking, posting and revisions will be performed via electronic means by using the FDM touch screen or the attached keyboard and mouse.

- **a.** Ground Control shall ensure that departing aircraft have received the current weather via the Automatic Terminal Information Service (ATIS), and enter the appropriate code via the FDM edit window.
- **b.** Ground Control strips will be passed to Local Control by selecting LC button.
- **c.** Local Control strips will be passed to departure by selecting the DPT button on the right side of the LC strip. Other action buttons to represent Line up and Wait and Takeoff clearance issued will be available.



AAL1122 TRISS3 17R EG P1740
B752/Q B BOS 38 FRC E1800
> SWAP <NRP
LC

EGF3309 GARL3 17R EF P1705
E145/Q S KTXK 170
DPT

Figure E2. Example Electronic Flight Strips.

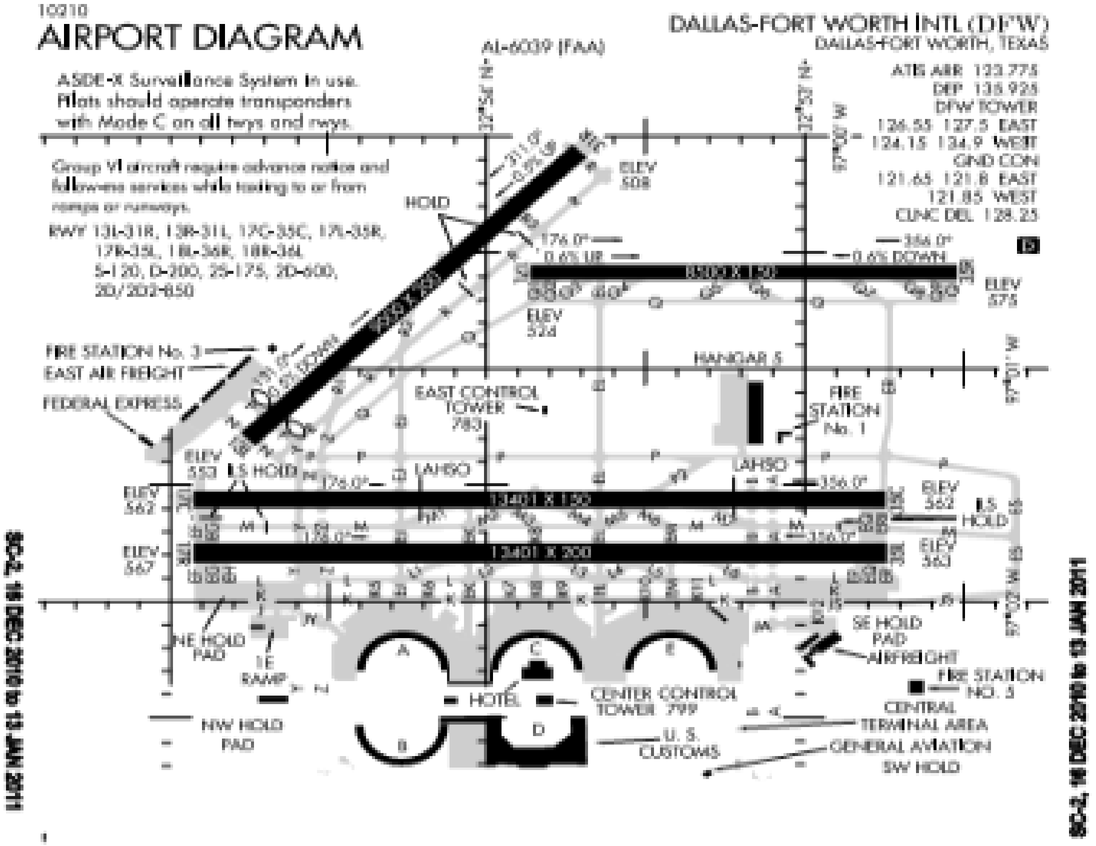


Figure E3. Airport Diagram.

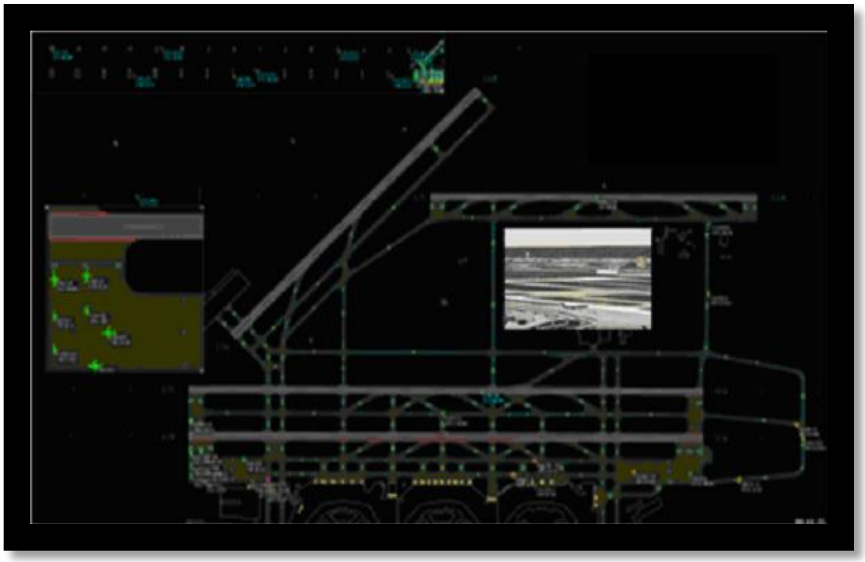


Figure E4. Example Camera Display.

All tower situation displays will be considered certified for separation. If aircraft are not visible out-the-window, all surveillance displays can be used to determine aircraft position for separation purposes.

Observation of traffic on the TIDS and/or camera displays satisfies all existing requirements for "visual observation" in FAA Order 7110.65T.

Visual scan of all movement areas will be performed by members of the tower team.

a. Local Control shall scan runways to the maximum extent possible. In all scenarios, scanning of the TIDS and/or Camera displays satisfies this requirement.

b. Ground Control shall assist local control in scanning runways, especially when runways are in close proximity to other movement areas. In all scenarios, scanning of the TIDS and/or Camera displays satisfies this requirement.

Ground Control shall be responsible for the ground movement of aircraft and radio-equipped vehicular traffic on the east side of the airport, excluding active runways. Ground Control controls traffic on bridges Z and B. Local Control will retain control of arrivals until they have been cleared to cross all active runways along their taxi route, or have been issued instructions to taxi via perimeter taxiway ES.

Ground control shall:

a. Initiate coordination for crossing of an active runway directly with LC.

PHRASEOLOGY-
CROSS(runway)AT (intersection)WITH (company/type aircraft).

b. Advise LC when the coordinated runway crossing is complete.

PHRASEOLOGY-
CLEAROF (runway).

c. Verbally advise LC of any aircraft taxied to an intersection for departure.

d. Forward flight progress strips to LC. Electronic strips shall be forwarded by selecting the "LC" action button on the electronic strip.

e. Regulate, to the extent practical, the sequence of departure traffic so that routings differ between successive departures.

Local Control is responsible for separating aircraft on all active runways and within delegated tower airspace on the east side. Local Control shall be responsible for runway crossings. These exercises will employ a simulation of DFW traffic only, but when over flight and helicopter traffic is encountered in shadow operations, the procedures outlined in local directives will be adhered to.

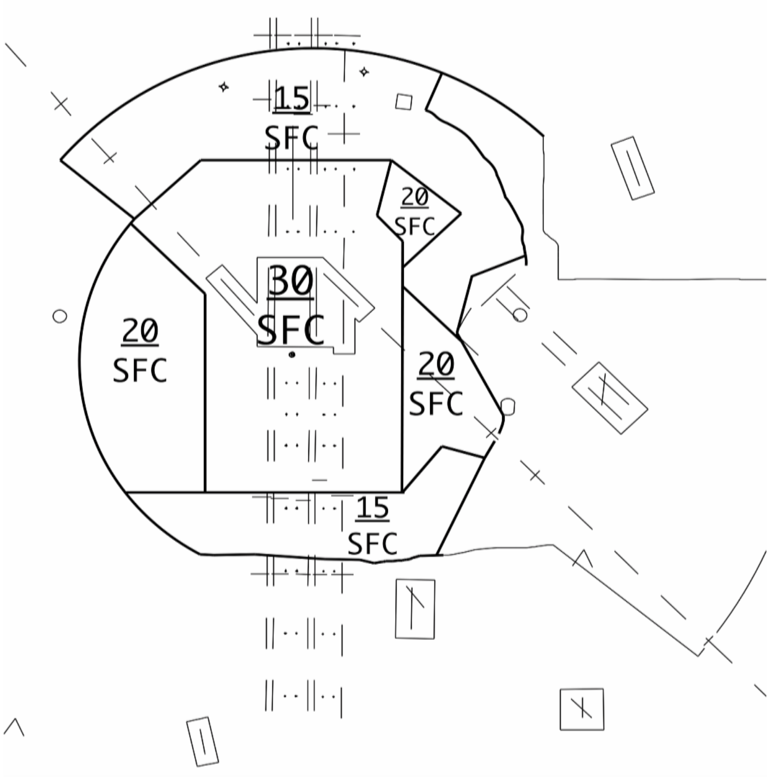


Figure E5. DFW Delegated Airspace – North Flow.

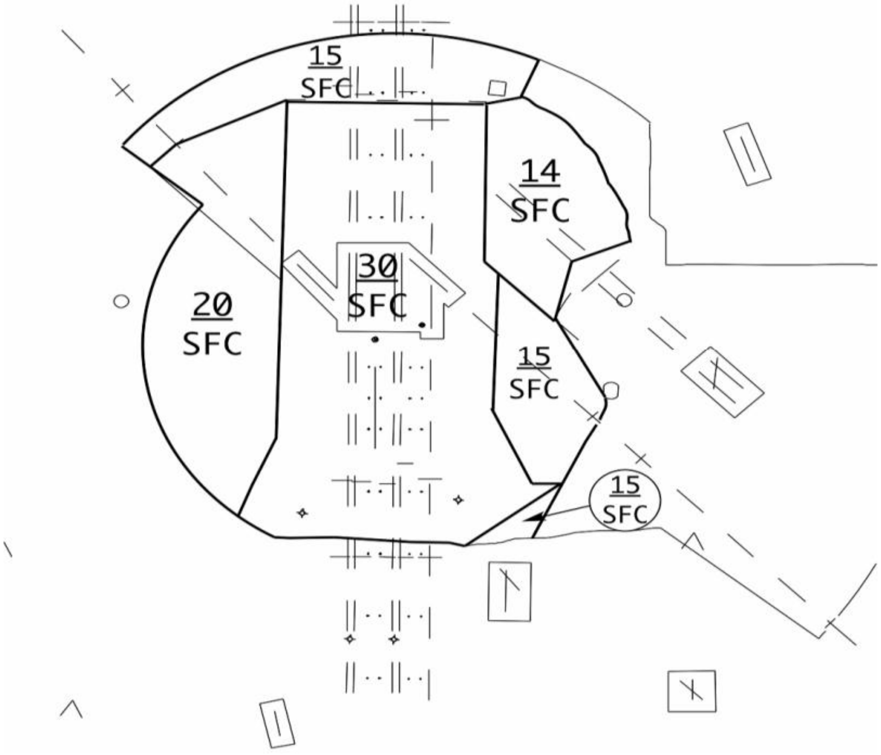


Figure E6. DFW Delegated Airspace – South Flow.

Local Control shall:

- **a.** Coordinate with GC, as necessary, to facilitate runway crossings.
- **b.** Advise missed approaches to fly runway heading and contact departure. No additional coordination is necessary.
- **c.** Forward departure information to TRACON by selecting the “DPT” action button on electronic flight strips.

Test participants will be expected to adhere to standards and procedures outlined in FAA and local directives and issue control instructions accordingly.

- **a.** Line up and wait (LUAW) operations are allowed on runways in accordance with FAA JO 7110.65T, FAA JO 7210.3 and DFWO 7110.65.
- **b.** Tower is responsible for ensuring standard separation between:
    - **1.** Successive Departures
    - **2.** Departures and Arrivals
    - **3.** All other traffic operating within tower airspace

All surveillance data needed to apply separation standards can be obtained from the surveillance displays (Camera, TIDS, RACD).

In scenarios where OTW is provided, the controllers will use the camera to supplement and enhance the situation awareness gains achieved by looking out the window or use of the surveillance displays. Recommended applications include but are not limited to:

- Visually scanning runway before and during landing or takeoff
- Observing gear status during landing or takeoff
- Confirming aircraft or vehicle identity and position prior to issuing control instruction
- Preemptive conformance monitoring
- Confirming or ruling out the existence of traffic when there is missing and/or extraneous surveillance targets
- Applying visual separation on tower controlled traffic
- Visual observation of bird/animal activity
- Detecting and identifying FOD
- Observing and detecting non-transponder equipped vehicular targets

When the OTW is not provided, the camera images will be the sole source of visual information and may be used to perform the tasks mentioned in the previous paragraph. Four stitched-together camera images will provide a panoramic view to supplement the OTW, and may act as a substitute when the OTW is not available. Controllers may use this camera image to:

- Scan airport traffic for conformance monitoring
- Scan airport movement and non-movement areas to identify conflicts and visually confirm location of aircraft or vehicle before issuing control instructions.
- Apply separation criteria while controlling airport traffic
- Crosscheck visually obtained aircraft data with surveillance data

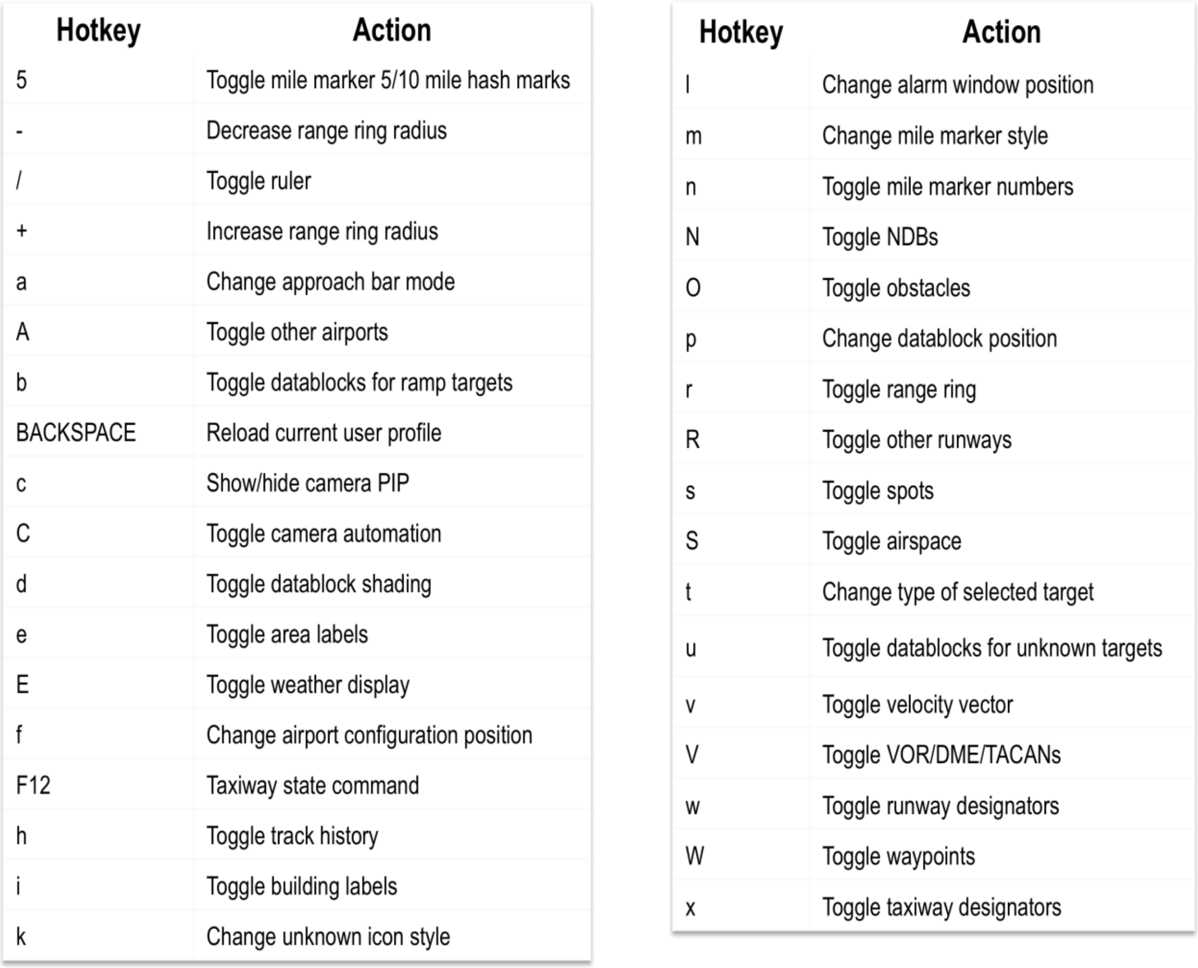
A scanning camera with pan-tilt-zoom capability will give the controller the ability to select any aircraft or vehicle on the surveillance display to be auto-tracked along its transition into, out of, or within the airport environment. This camera will be equipped with intelligent logic that will enable automatic panning and zooming to a target of interest because an off-nominal event is occurring. The following is a list of the off-nominal events that will take the camera into automatic mode:

- Aircraft crosses active runway
- Aircraft stops on runway

Two fixed cameras will provide a view of the north or south threshold. These images will be depicted as a window on the external camera display. The threshold to be viewed depends on the chosen configuration of the display.

To initiate scanning camera auto-tracking of a target of interest, right-click on an aircraft or vehicle target, or select any spot on the airfield for close up observation. This image will be displayed as a window on an external monitor but can also be displayed as a PiP on the TIDS as a toggle on/off by depressing “c” on the TIDS keyboard. To utilize the zoom capability, rotate the mouse wheel forward or backward to zoom in and zoom out. The image can be centered, if necessary, by left clicking on a target or image area. The scanning cameras will also be programmed with “intelligent logic” in order to identify and zoom to aircraft involved in certain emergency or off-nominal situations. If the user manually selects a target to track, the automation is disabled and the camera reverts to manual mode.

A Complete List of TIDS Hot Keys.



Hotkey	Action
5	Toggle mile marker 5/10 mile hash marks
-	Decrease range ring radius
/	Toggle ruler
+	Increase range ring radius
a	Change approach bar mode
A	Toggle other airports
b	Toggle datablocks for ramp targets
BACKSPACE	Reload current user profile
c	Show/hide camera PIP
C	Toggle camera automation
d	Toggle datablock shading
e	Toggle area labels
E	Toggle weather display
f	Change airport configuration position
F12	Taxiway state command
h	Toggle track history
i	Toggle building labels
k	Change unknown icon style

Hotkey	Action
l	Change alarm window position
m	Change mile marker style
n	Toggle mile marker numbers
N	Toggle NDBs
O	Toggle obstacles
p	Change datablock position
r	Toggle range ring
R	Toggle other runways
s	Toggle spots
S	Toggle airspace
t	Change type of selected target
u	Toggle datablocks for unknown targets
v	Toggle velocity vector
V	Toggle VOR/DME/TACANs
w	Toggle runway designators
W	Toggle waypoints
x	Toggle taxiway designators

Figure E7. TIDS Hot Keys.

Appendix F: Camera Display Options

Potential Camera Display Options

Panoramic Camera

Fixed Camera

Scanning Camera (Cohu)

CAMERA EXTERNAL MONITOR DISPLAY

An external monitor was available and presented a panoramic view along with fixed camera view and scanning camera view.

Appendix G: Post-Run Questionnaire

Post-Run Questionnaire

Controller # ____________________ **Date: _____June 2011_____**

Please answer the following questions based upon your experience in the scenario just completed by **clicking on the number** that corresponds to your rating. Click N/A if the question is not applicable to this scenario.

1. Rate the degree to which each display helped **maintain awareness of aircraft identity** during this scenario.			N/A	
a. Out-the-Window Display	Very Little	①②③④⑤⑥⑦	○	Very Much
b. TIDS Display	Very Little	①②③④⑤⑥⑦	○	Very Much
c. FDM Display	Very Little	①②③④⑤⑥⑦	○	Very Much
d. Camera View - Auxiliary	Very Little	①②③④⑤⑥⑦	○	Very Much
i. Cohu	Very Little	①②③④⑤⑥⑦	○	Very Much
ii. Fixed	Very Little	①②③④⑤⑥⑦	○	Very Much
iii. Panoramic	Very Little	①②③④⑤⑥⑦	○	Very Much
e. Picture-in-Picture Cohu	Very Little	①②③④⑤⑥⑦	○	Very Much

2. Rate the degree to which each display helped **maintain awareness of traffic location** during this scenario.			N/A	
a. Out-the Window Display	Very Little	①②③④⑤⑥⑦	○	Very Much
b. TIDS Display	Very Little	①②③④⑤⑥⑦	○	Very Much
c. FDM Display	Very Little	①②③④⑤⑥⑦	○	Very Much
d. Camera View - Auxiliary	Very Little	①②③④⑤⑥⑦	○	Very Much
i. Cohu	Very Little	①②③④⑤⑥⑦	○	Very Much
ii. Fixed	Very Little	①②③④⑤⑥⑦	○	Very Much
iii. Panoramic	Very Little	①②③④⑤⑥⑦	○	Very Much
e. Picture-in-Picture Cohu	Very Little	①②③④⑤⑥⑦	○	Very Much

3. Rate the degree to which each display helped **predict/anticipate aircraft position** during this scenario.			N/A	
a. Out-the Window Display	Very Little	①②③④⑤⑥⑦	○	Very Much
b. TIDS Display	Very Little	①②③④⑤⑥⑦	○	Very Much
c. FDM Display	Very Little	①②③④⑤⑥⑦	○	Very Much
d. Camera View	Very Little	①②③④⑤⑥⑦	○	Very Much
i. Cohu	Very Little	①②③④⑤⑥⑦	○	Very Much
ii. Fixed	Very Little	①②③④⑤⑥⑦	○	Very Much
iii. Panoramic	Very Little	①②③④⑤⑥⑦	○	Very Much
e. Picture-in-Picture Cohu	Very Little	①②③④⑤⑥⑦	○	Very Much

4. Rate the degree to which each display increased your **ability to detect aircraft** during this scenario.			N/A	
a. Out-the Window Display	Very Little	①②③④⑤⑥⑦	○	Very Much
b. TIDS Display	Very Little	①②③④⑤⑥⑦	○	Very Much
c. FDM Display	Very Little	①②③④⑤⑥⑦	○	Very Much
d. Camera View	Very Little	①②③④⑤⑥⑦	○	Very Much
i. Cohu	Very Little	①②③④⑤⑥⑦	○	Very Much
ii. Fixed	Very Little	①②③④⑤⑥⑦	○	Very Much
iii. Panoramic	Very Little	①②③④⑤⑥⑦	○	Very Much
e. Picture-in-Picture Cohu	Very Little	①②③④⑤⑥⑦	○	Very Much

5. Rate the degree to which each display helped you **maintain efficient operations** during this scenario			N/A	
a. Out-the Window Display	Very Little	①②③④⑤⑥⑦	○	Very Much
b. TIDS Display	Very Little	①②③④⑤⑥⑦	○	Very Much
c. FDM Display	Very Little	①②③④⑤⑥⑦	○	Very Much
d. Camera View	Very Little	①②③④⑤⑥⑦	○	Very Much
i. Cohu	Very Little	①②③④⑤⑥⑦	○	Very Much
ii. Fixed	Very Little	①②③④⑤⑥⑦	○	Very Much
iii. Panoramic	Very Little	①②③④⑤⑥⑦	○	Very Much
e. Picture-in-Picture Cohu	Very Little	①②③④⑤⑥⑦	○	Very Much

6. Rate the degree to which each display helped you **maintain safe operations** during this scenario			N/A	
a. Out-the Window Display	Very Little	①②③④⑤⑥⑦	○	Very Much
b. TIDS Display	Very Little	①②③④⑤⑥⑦	○	Very Much
c. FDM Display	Very Little	①②③④⑤⑥⑦	○	Very Much
d. Camera View	Very Little	①②③④⑤⑥⑦	○	Very Much
i. Cohu	Very Little	①②③④⑤⑥⑦	○	Very Much
ii. Fixed	Very Little	①②③④⑤⑥⑦	○	Very Much
iii. Panoramic	Very Little	①②③④⑤⑥⑦	○	Very Much
e. Picture-in-Picture Cohu	Very Little	①②③④⑤⑥⑦	○	Very Much

7. Rate the degree to which each display helped you **maintain awareness regarding potential runway incursions** during this scenario			N/A	
a. Out-the Window Display	Very Little	①②③④⑤⑥⑦	○	Very Much
b. TIDS Display	Very Little	①②③④⑤⑥⑦	○	Very Much
c. FDM Display	Very Little	①②③④⑤⑥⑦	○	Very Much
d. Camera View	Very Little	①②③④⑤⑥⑦	○	Very Much
i. Cohu	Very Little	①②③④⑤⑥⑦	○	Very Much
ii. Fixed	Very Little	①②③④⑤⑥⑦	○	Very Much
iii. Panoramic	Very Little	①②③④⑤⑥⑦	○	Very Much
e. Picture-in-Picture Cohu	Very Little	①②③④⑤⑥⑦	○	Very Much

8. Rate the degree to which each display helped you **respond to any off-nominal events** during this scenario			N/A	
a. Out-the Window Display	Very Little	①②③④⑤⑥⑦	○	Very Much
b. TIDS Display	Very Little	①②③④⑤⑥⑦	○	Very Much
c. FDM Display	Very Little	①②③④⑤⑥⑦	○	Very Much
d. Camera View	Very Little	①②③④⑤⑥⑦	○	Very Much
i. Cohu	Very Little	①②③④⑤⑥⑦	○	Very Much
ii. Fixed	Very Little	①②③④⑤⑥⑦	○	Very Much
iii. Panoramic	Very Little	①②③④⑤⑥⑦	○	Very Much
e. Picture-in-Picture Cohu	Very Little	①②③④⑤⑥⑦	○	Very Much

9. Rate your **workload** during this scenario with regard to the following:			N/A	
a. Overall **workload**	Very Low	①②③④⑤⑥⑦	○	Very High
b. **Workload** due to communications with pilots	Very Low	①②③④⑤⑥⑦	○	Very High
c. **Workload** due to off-nominal events	Very Low	①②③④⑤⑥⑦	○	Very High
d. **Workload** due to coordination with the ground/local controller	Very Low	①②③④⑤⑥⑦	○	Very High
e. **Workload** due to overall interactions with the auxiliary camera displays	Very Low	①②③④⑤⑥⑦	○	Very High
i. Cohu	Very Low	①②③④⑤⑥⑦	○	Very High
ii. Fixed	Very Low	①②③④⑤⑥⑦	○	Very High
iii. Panoramic	Very Low	①②③④⑤⑥⑦	○	Very High
f. **Workload** due to interactions with the Picture-in-Picture cohu camera display	Very Low	①②③④⑤⑥⑦	○	Very High
g. **Workload** due to toggling the fixed camera images	Very Low	①②③④⑤⑥⑦	○	Very High

10. Rate your **situation awareness** during this scenario with regard to the following:			N/A	
a. **Overall level of situation awareness**	Very Low	①②③④⑤⑥⑦	○	Very High
b. **Situational awareness** due to communications with pilots	Very Low	①②③④⑤⑥⑦	○	Very High
c. **Situational awareness** due to off-nominal events	Very Low	①②③④⑤⑥⑦	○	Very High
d. **Situational awareness** due to coordination with the ground/local controller	Very Low	①②③④⑤⑥⑦	○	Very High
e. **Situational awareness** due to overall interactions with the auxiliary camera display	Very Low	①②③④⑤⑥⑦	○	Very High
i. Cohu	Very Low	①②③④⑤⑥⑦	○	Very High
ii. Fixed	Very Low	①②③④⑤⑥⑦	○	Very High
iii. Panoramic	Very Low	①②③④⑤⑥⑦	○	Very High
f. **Situational awareness** due to interactions with the Picture-in-Picture Cohu camera display	Very Low	①②③④⑤⑥⑦	○	Very High
g. **Situational awareness** due to toggling the fixed camera images	Very Low	①②③④⑤⑥⑦	○	Very High

11. How much interaction did you have with the following software components during this scenario			N/A	
a. The auxiliary camera display	Very Little	①②③④⑤⑥⑦	○	Very Much
i. Cohu	Very Little	①②③④⑤⑥⑦	○	Very Much
ii. Fixed	Very Little	①②③④⑤⑥⑦	○	Very Much
iii. Panoramic	Very Little	①②③④⑤⑥⑦	○	Very Much
b. Picture-in-Picture Cohu camera display	Very Little	①②③④⑤⑥⑦	○	Very Much

Definitions for NASA Taskload Index (NASA-TLX)

Mental Demand – how much mental and perceptual activity was required (e.g., thinking, deciding, calculating, remembering, looking, searching, etc.)? Were your tasks easy or demanding, simple or complex, exacting or forgiving?

Physical Demand – how much physical activity was required (e.g., talking, pointing, etc.)? Were your tasks easy or demanding, slow or brisk, slack or strenuous, restful or laborious?

Temporal Demand – how much time pressure did you feel due to the rate or pace at which your tasks occurred? Was the pace slow and leisurely or rapid and frantic?

Performance – how successful do you think you were in accomplishing the goals of your tasks? How satisfied were you with your performance in accomplishing these goals?

Effort – how hard did you have to work (mentally and physically) to accomplish this level of performance?

Frustration – how insecure, discouraged, irritated, stressed, and annoyed versus secure, gratified, content, relaxed, and complacent did you feel in performing your tasks?

12. Modified NASA-TLX scale (ratings from 1-7):			
a. Rate your mental demand during this scenario	Extremely Low	①②③④⑤⑥⑦	Extremely High
b. Rate your physical demand during this scenario	Extremely Low	①②③④⑤⑥⑦	Extremely High
c. Rate your temporal demand during this scenario	Extremely Low	①②③④⑤⑥⑦	Extremely High
d. Rate your performance during this scenario	Extremely Low	①②③④⑤⑥⑦	Extremely High
e. Rate your effort during this scenario.	Extremely Low	①②③④⑤⑥⑦	Extremely High
f. Rate your frustration during this scenario.	Extremely Low	①②③④⑤⑥⑦	Extremely High

13. What did you most want to see displayed on the Camera Display for this scenario? (For example, approach area, intersections, line-of-sight areas, areas of alert, etc.)

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14. Are there any CHI issues you noticed during this scenario? (Please detail whether the issues were with the TIDS, FDM, or the Camera display)

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15. Do you have any additional comments or clarifications about your experience during this scenario?

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Appendix H: Post-Evaluation Questionnaire

Post Evaluation Questionnaire

Please answer the following questions based upon your entire experience this week by **clicking on the number** that corresponds to your rating.

How easy was it to

1. Select a viewing area			
a. PIP Cohu	Very Difficult	①②③④⑤⑥⑦	Very Easy
b. Auxiliary Cohu	Very Difficult	①②③④⑤⑥⑦	Very Easy
2. Resize a viewing area			
a. PIP Cohu	Very Difficult	①②③④⑤⑥⑦	Very Easy
b. Auxiliary Cohu	Very Difficult	①②③④⑤⑥⑦	Very Easy
3. Select a target (i.e. aircraft or vehicle)			
a. PIP Cohu	Very Difficult	①②③④⑤⑥⑦	Very Easy
b. Auxiliary Cohu	Very Difficult	①②③④⑤⑥⑦	Very Easy
4. Track an aircraft target			
a. PIP Cohu	Very Difficult	①②③④⑤⑥⑦	Very Easy
b. Auxiliary Cohu	Very Difficult	①②③④⑤⑥⑦	Very Easy
5. Zoom to a viewing area			
a. PIP Cohu	Very Difficult	①②③④⑤⑥⑦	Very Easy
b. Auxiliary Cohu	Very Difficult	①②③④⑤⑥⑦	Very Easy
6. Pan to a viewing area			
a. PIP Cohu	Very Difficult	①②③④⑤⑥⑦	Very Easy
b. Auxiliary Cohu	Very Difficult	①②③④⑤⑥⑦	Very Easy
7. Tilt to a viewing area			
a. PIP Cohu	Very Difficult	①②③④⑤⑥⑦	Very Easy
b. Auxiliary Cohu	Very Difficult	①②③④⑤⑥⑦	Very Easy
8. Determine the location of an aircraft			
a. PIP Cohu	Very Difficult	①②③④⑤⑥⑦	Very Easy
b. Auxiliary Cohu	Very Difficult	①②③④⑤⑥⑦	Very Easy

9. Determine the aircraft type/company			
a. PIP Cohu	Very Difficult	①②③④⑤⑥⑦	Very Easy
b. Auxiliary Cohu	Very Difficult	①②③④⑤⑥⑦	Very Easy

10. Determine the location of an aircraft			
a. PIP Cohu	Very Difficult	①②③④⑤⑥⑦	Very Easy
b. Auxiliary Cohu	Very Difficult	①②③④⑤⑥⑦	Very Easy
c. Fixed Views	Very Difficult	①②③④⑤⑥⑦	Very Easy
d. Panoramic View	Very Difficult	①②③④⑤⑥⑦	Very Easy
11. Determine the aircraft type/company			
a. PIP Cohu	Very Difficult	①②③④⑤⑥⑦	Very Easy
b. Auxiliary Cohu	Very Difficult	①②③④⑤⑥⑦	Very Easy
c. Fixed Views	Very Difficult	①②③④⑤⑥⑦	Very Easy
d. Panoramic View	Very Difficult	①②③④⑤⑥⑦	Very Easy

Rate the following:

12. The ability to track a target			
a. PIP Cohu	Completely Inadequate	①②③④⑤⑥⑦	Completely Adequate
b. Auxiliary Cohu	Completely Inadequate	①②③④⑤⑥⑦	Completely Adequate
c. Fixed Views	Completely Inadequate	①②③④⑤⑥⑦	Completely Adequate
d. Panoramic View	Completely Inadequate	①②③④⑤⑥⑦	Completely Adequate
13. The overall automatic camera scanning functionality			
a. PIP Cohu	Completely Inadequate	①②③④⑤⑥⑦	Completely Adequate
b. Auxiliary Cohu	Completely Inadequate	①②③④⑤⑥⑦	Completely Adequate
c. Fixed Views	Completely Inadequate	①②③④⑤⑥⑦	Completely Adequate
d. Panoramic View	Completely Inadequate	①②③④⑤⑥⑦	Completely Adequate

14. The ability to detect aircraft non-conformance			
a. PIP Cohu	Completely Inadequate	①②③④⑤⑥⑦	Completely Adequate
b. Auxiliary Cohu	Completely Inadequate	①②③④⑤⑥⑦	Completely Adequate
c. Fixed Views	Completely Inadequate	①②③④⑤⑥⑦	Completely Adequate
d. Panoramic View	Completely Inadequate	①②③④⑤⑥⑦	Completely Adequate

15. The ability to maintain overall situation awareness			
a. PIP Cohu	Completely Inadequate	①②③④⑤⑥⑦	Completely Adequate
b. Auxiliary Cohu	Completely Inadequate	①②③④⑤⑥⑦	Completely Adequate
c. Fixed Views	Completely Inadequate	①②③④⑤⑥⑦	Completely Adequate
d. Panoramic View	Completely Inadequate	①②③④⑤⑥⑦	Completely Adequate

Please rate the following**:**

16. The overall benefit for **supplemental** SNT operations			
a. of the **PiP camera display**	Completely Unnecessary	①②③④⑤⑥⑦	Completely Necessary
b. of the **auxiliary camera display**	Completely Unnecessary	①②③④⑤⑥⑦	Completely Necessary
17. The overall benefit for **contingency** SNT operations			
a. of the **PiP camera**	Completely Unnecessary	①②③④⑤⑥⑦	Completely Necessary
b. of the **auxiliary camera display**	Completely Unnecessary	①②③④⑤⑥⑦	Completely Necessary
18. The overall presentation			
a. on the **PiP camera display**	Completely Inadequate	①②③④⑤⑥⑦	Completely Adequate
b. on the **auxiliary camera display**	Completely Inadequate	①②③④⑤⑥⑦	Completely Adequate
19. The overall resolution on the **auxiliary camera display**			
a. on the **PiP camera display**	Completely Inadequate	①②③④⑤⑥⑦	Completely Adequate
b. on the **auxiliary camera display**	Completely Inadequate	①②③④⑤⑥⑦	Completely Adequate

20. The overall functionality			
a. of the **PiP camera display**	Completely Inadequate	①②③④⑤⑥⑦	Completely Adequate
b. of the **auxiliary camera display**	Completely Inadequate	①②③④⑤⑥⑦	Completely Adequate
21. The alerting capability for off-nominal events			
a. on the **PiP camera display**	Completely Unacceptable	①②③④⑤⑥⑦	Completely Acceptable
b. on the **auxiliary camera display**	Completely Unacceptable	①②③④⑤⑥⑦	Completely Acceptable

22. The system lag			
a. on the **PiP camera display**	Completely Unacceptable	①②③④⑤⑥⑦	Completely Acceptable
b. on the **auxiliary camera display**	Completely Unacceptable	①②③④⑤⑥⑦	Completely Acceptable
23. Auxiliary camera display only:			
a. The layout of the inset windows on the **auxiliary camera display**	Completely Inadequate	①②③④⑤⑥⑦	Completely Adequate
b. The size of the **auxiliary camera display**	Completely Inadequate	①②③④⑤⑥⑦	Completely Adequate
c. The readability of the text on the **auxiliary camera display**	Completely Inadequate	①②③④⑤⑥⑦	Completely Adequate

24. Rate the importance of depicting the following information on a camera display in a **Supplemental SNT** environment:			
a. Panoramic view of entire airport	Completely Unnecessary	①②③④⑤⑥⑦	Essential
b. Approach area	Completely Unnecessary	①②③④⑤⑥⑦	Essential
c. Runway Intersections	Completely Unnecessary	①②③④⑤⑥⑦	Essential
d. Blocked line-of-sight areas	Completely Unnecessary	①②③④⑤⑥⑦	Essential
e. Areas/aircraft under alert conditions	Completely Unnecessary	①②③④⑤⑥⑦	Essential
f. Controller selectable areas	Completely Unnecessary	①②③④⑤⑥⑦	Essential
Other? Please list.			

Comments

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25. Rate the importance of depicting the following information on a camera display in a **Contingency SNT** environment:			
a. Panoramic view of entire airport	Completely Unnecessary	①②③④⑤⑥⑦	Essential
b. Approach area	Completely Unnecessary	①②③④⑤⑥⑦	Essential
c. Runway Intersections	Completely Unnecessary	①②③④⑤⑥⑦	Essential
d. Blocked line-of-sight areas	Completely Unnecessary	①②③④⑤⑥⑦	Essential
e. Areas/aircraft under alert conditions	Completely Unnecessary	①②③④⑤⑥⑦	Essential
f. Controller selectable areas	Completely Unnecessary	①②③④⑤⑥⑦	Essential
Other? Please list.			

Comments

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26. How would you use the Camera Display in a **Supplemental** SNT environment? (For example, binoculars view, line-of-sight areas, areas of alert, etc.)

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27. How would you use the Camera Display in a **Contingency** SNT environment? (For example, binoculars view, line-of-sight areas, areas of alert, etc.)

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28. Please enter any additional comments regarding the camera views display. Are there any features that need to be added, modified, or removed?

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29. Please enter any comments regarding your view of the Supplemental SNT concept:

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30. Please enter any comments regarding your view of the Contingency SNT concept:

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Regarding the functionality of the TIDS, how easy was it to:

31. Select a data block	Very Difficult	①②③④⑤⑥⑦	Very Easy
32. Deselect a data block	Very Difficult	①②③④⑤⑥⑦	Very Easy
33. Move a data block	Very Difficult	①②③④⑤⑥⑦	Very Easy
34. Maintain data block separation	Very Difficult	①②③④⑤⑥⑦	Very Easy
35. Detect aircraft location/position	Very Difficult	①②③④⑤⑥⑦	Very Easy
36. Determine aircraft type	Very Difficult	①②③④⑤⑥⑦	Very Easy
37. Determine aircraft weight class	Very Difficult	①②③④⑤⑥⑦	Very Easy
38. Determine aircraft airborne/ground status	Very Difficult	①②③④⑤⑥⑦	Very Easy
39. Find necessary flight information	Very Difficult	①②③④⑤⑥⑦	Very Easy
40. Maintain Situation Awareness	Very Difficult	①②③④⑤⑥⑦	Very Easy
41. Create a PiP window to view other areas of the airport (approach, bridge, etc.)	Very Difficult	①②③④⑤⑥⑦	Very Easy
42. Manipulate (resize, move, etc.) the PiP window	Very Difficult	①②③④⑤⑥⑦	Very Easy

Please rate the adequacy of:

43. The size of overall display	Inadequate	①②③④⑤⑥⑦	Adequate
44. The size of the icons/text/data blocks	Inadequate	①②③④⑤⑥⑦	Adequate
45. The picture-in-picture (PIP) capability	Inadequate	①②③④⑤⑥⑦	Adequate
46. The color schema of icons/text	Inadequate	①②③④⑤⑥⑦	Adequate
47. The data block time sharing	Inadequate	①②③④⑤⑥⑦	Adequate
48. The data block presentation	Inadequate	①②③④⑤⑥⑦	Adequate

49. Please enter any additional comments regarding the TIDS display. Are there any features that you believe need to be added, modified, or removed?

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Regarding the functionality of the **FDM**, how easy was it to:

50. Select a flight strip	Very Difficult	①②③④⑤⑥⑦	Very Easy
51. Deselect a flight strip	Very Difficult	①②③④⑤⑥⑦	Very Easy
52. Undo an action/correct an error	Very Difficult	①②③④⑤⑥⑦	Very Easy
53. Determine aircraft location	Very Difficult	①②③④⑤⑥⑦	Very Easy
54. Transfer flight information	Very Difficult	①②③④⑤⑥⑦	Very Easy
55. Edit flight information	Very Difficult	①②③④⑤⑥⑦	Very Easy
56. Find flight information	Very Difficult	①②③④⑤⑥⑦	Very Easy
57. Manage flight strips	Very Difficult	①②③④⑤⑥⑦	Very Easy

Please rate the adequacy of:

58. The strip bay configuration	Inadequate	①②③④⑤⑥⑦	Adequate
59. The Information presentation	Inadequate	①②③④⑤⑥⑦	Adequate
60. The type of information presented	Inadequate	①②③④⑤⑥⑦	Adequate
61. The size of the display	Inadequate	①②③④⑤⑥⑦	Adequate
62. The readability of the text	Inadequate	①②③④⑤⑥⑦	Adequate

63. Please enter any additional comments regarding the FDM display. Are there any features that need to be added, modified, or removed, including any “memory aid” capabilities?

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Appendix I: Simulation Realism Questionnaire

Simulation Realism Questionnaire

Simulation Realism and Research Apparatus Ratings

1.	How **realistic** was the overall simulation experience compared to actual ATC operations?	Not at all	1 2 3 4 5 6 7 8 9 10	Extremely Realistic
2.	Thinking about the traffic scenarios, how **representative** were they of a typical workday at your facility?	Not at all	1 2 3 4 5 6 7 8 9 10	Extremely Representative
3.	Thinking about the traffic scenarios, how **realistic** were the traffic patterns compared to actual NAS traffic?	Not at all	1 2 3 4 5 6 7 8 9 10	Extremely Realistic
4.	How **realistic was the out-the-window view** compared to an actual OTW view?	Not at all	1 2 3 4 5 6 7 8 9 10	Extremely Realistic
5.	How **realistic was the TIDS software** compared to an ASDE-X?	Not at all	1 2 3 4 5 6 7 8 9 10	Extremely Realistic
6.	How **realistic was the TIDS hardware** compared to an ASDE-X?	Not at all	1 2 3 4 5 6 7 8 9 10	Extremely Realistic
7.	How well did the **simulation pilots** respond to your clearances in terms of traffic movement and callbacks?	Not at all	1 2 3 4 5 6 7 8 9 10	Extremely Well
8.	How **realistic was the simulated tower environment** compared to actual field operations.	Not at all	1 2 3 4 5 6 7 8 9 10	Extremely Realistic

9. How effective was the **training** provided on each of the following systems:			
TIDS	Not at all	1 2 3 4 5 6 7 8 9 10	Extremely Effective
FDM	Not at all	1 2 3 4 5 6 7 8 9 10	Extremely Effective
Auxiliary Camera Display	Not at all	1 2 3 4 5 6 7 8 9 10	Extremely Effective
Cohu Camera on Auxiliary Display	Not at all	1 2 3 4 5 6 7 8 9 10	Extremely Effective
Cohu Camera –PiP	Not at all	1 2 3 4 5 6 7 8 9 10	Extremely Effective
Fixed Camera Images on Auxiliary Display	Not at all	1 2 3 4 5 6 7 8 9 10	Extremely Effective
10. To what extent, if any, did the oculometer interfere with your ATC performance?	Not at all	1 2 3 4 5 6 7 8 9 10	Extreme interference

11. Please include any additional comments about the simulation that you would like us to know about.

12. Do you have any comments or suggestions for improving our simulation capability?

Appendix J: Scenario for High Impact Off-Nominal

Scenario for High Impact Off-Nominal

Participants:

1. AAL2479 an MD-88 declaring emergency
2. Controller
3. 3 Port Authority Trucks
    a. Port Control 1 to Z via P
    b. Port Control 2 (Can originate from the fire station) - Goes to taxiway EJ via P
    c. Port Control 3 - Goes to taxiway EL via P
4. 3 Fire Trucks
    a. Fire Chief (DFW Command) From Fire Station 1 goes to Z via P
    b. Fire 2 From Fire Station 1 goes to EJ via P
    c. Fire 3 From Fire Station 1 goes to EL via P

Aircraft Emergency Steps:

1. AAL2479 declares emergency.
2. The controller tells confederate supervisor who then contacts DPS --Fire/Port authority.
3. Port 1, Port 2, and Port 3 leave Fire Station # 1 and taxi to Papa to Z, EJ, and EL
    a. They hold short of 17C "Tower, l this is port control we are on the frequency 135.7"
4. Three Fire Trucks depart Fire Station 1 - FIRE TRUCKS first and then port vehicles and holds short of 17C.
    a. Fire 1 taxis P to EJ and holds short of 17C
    b. Fire 2 taxis P to EL and holds short of 17C
    c. Fire 3 taxis P to Z (fire chief)
5. AAL2479 lands and rolls to stop BETWEEN M4 and EL.
6. Port 1 calls to close runway (note: the instant the aircraft lands the port control calls the runway closed.
7. Fire 1 and Fire 2 follow behind AAL2479 as it is landing.
8. Port 1, Port 2, and Port 3 follow behind the fire trucks (check for FOD).
9. AAL2479 decides he is fine and tells the controller he is going to taxi (he turns Right at EL, then crosses 17R at EL).
10. Port 1, Port 2, and Port 3 finish checking for FOD.
11. The trucks get off the runway, tell the controller they are off, and follow the aircraft to the gate.
12. Port 1 tells the controller that 17C is open again. "Runway 17C has been inspected, runway open".
13. The fire and port authority trucks go back to fire station 1.

SAMPLE SCRIPT

Normal Handoff from TRACON to East Tower

AA2479: Tower AA2479 with you 20 NW for 17C
Tower: AA2479 DFW tower Cleared to Land Runway 17C
AA2479: Cleared to Land.

Emergency Notification

AA2497: Tower - we'd like to declare an emergency, we have smoke in the cockpit, and loss of primary flight instruments, over.

Tower: AA2479 - I understand, declaring an emergency, please state fuel on board, souls on board, over. Rescue on the way.

AA2497: We have 22,400 pounds of fuel and 133 passengers and crew.

Tower: Thank you, cleared to land runway 17C, wind calm.

Local Controller and others who are free, would most likely use binoculars to visually inspect the plane for wheels down and any sign of smoke. Concurrently, Local Control will advise the supervisor. Supervisor coordinates with TRACON, AA2479 last to land on 17C. Others go to 17R - Local Controller directs other landing traffic to 17R.

Crash Phone Activation - Ground Controller notifies Airport Fire Rescue (AFR) via the crash phone: providing as much information from the checklist below.

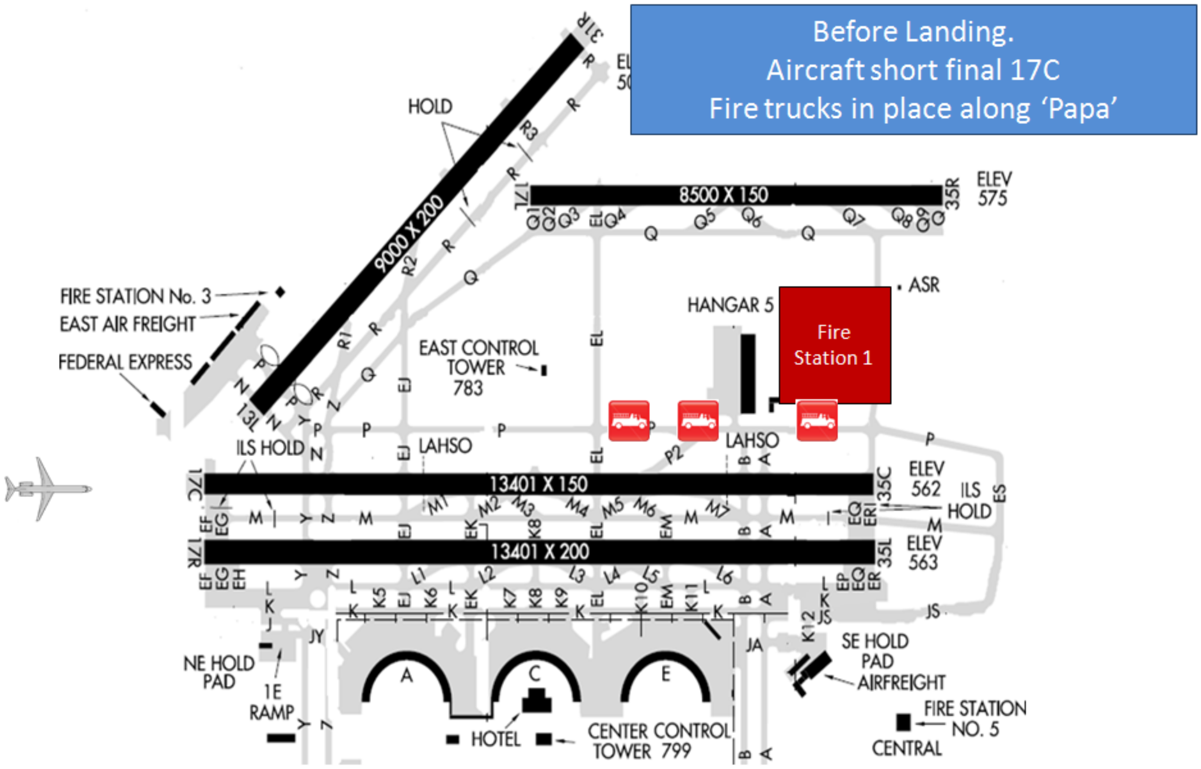
Ground Control: This is DFW East tower with an Alert II airborne emergency.

a. Type of aircraft: (American Airline flight 2479, an MD-80)
b. Location or ETA of the aircraft: (15 Miles Northwest, ETA 8 Minutes)
c. Nature of the emergency: (Smoke in cockpit, an loss of primary flight instruments)
d. Landing runway: (17C, wind calm)
e. Fuel remaining on board: (22,400 pounds of fuel)
f. Persons on hoard: (133)
g. Hazardous cargo or explosives: (Personnel Electronics)
h. Any specific request or information from the pilot: (Pilot will exit the runway when able)

Ground Controller: Questions? None.
Ground Controller: All parties released, tower out.

Aircraft Fire and Rescue

Rescue 1: DFW Tower (on an FM radio), over.
Ground Controller: Rescue 1, tower, go ahead.
Rescue 1: Rescue vehicles will deploy from Fire Station 1 along taxiway Papa, request permission to enter Taxiway Papa at Bravo, over.
Ground Control: Rescue 1 approved. Advise me prior to entering the runway.


Before Landing.
Aircraft short final 17C
Fire trucks in place along 'Papa'

Aircraft Lands

AA2479: Tower AA2479 landed without incident, off runway 17C at “Papa 2”, thanks for your help; contacting Ground.

Supervisor: calls to close Runway 17C for inspection.

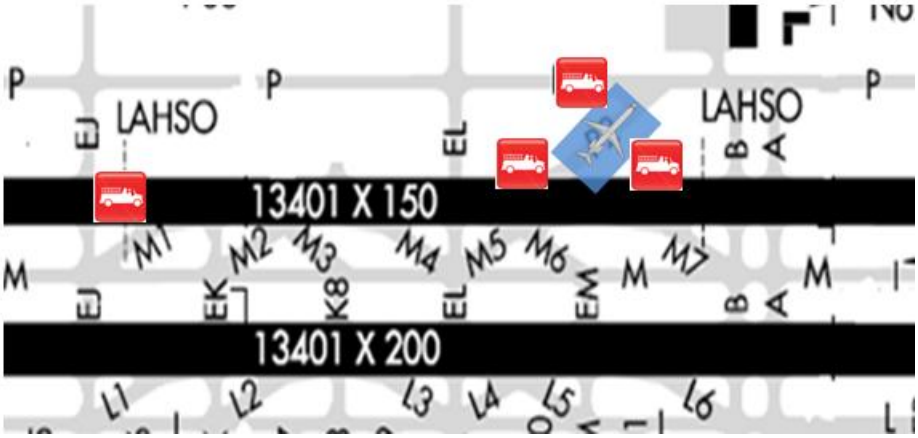
Rescue 1: DFW Tower, Rescue 1, request permission to enter runway 17C at taxiway EJ?
Ground Control: Rescue 1, DWF ground, enter runway 17C at EJ approved, advise when off.

Other rescue vehicles park within 10 feet of AA249.

Tower: AA2479, your welcome, contact ground.

AA2479: DFW ground AA2479 off runway 17C at “Papa 2” holding.

Ground Control: AA2479, roger Rescue 1 will contact you.



Rescue 1: DFW Tower, all vehicles are off runway 17C, and the emergency is terminated at 00:00.

Ground Control: Thank you Rescue 1.

Supervisor - Calls to re-open runway 17C.

Appendix K: Questionnaire Data

Questionnaire Data

BACKGROUND QUESTIONNAIRE DATA

		$\bar{x}$
2. Do you wear corrective lenses?		
Yes	6	
No	2	
3. What is your age?		44.38
4. Please answer the following (if you have no experience, enter 0):		
How long have you worked as a Certified Professional Controller (include both FAA and military experience)?		21.35
How long have you worked as a CPC for the FAA?		19.12
How long have you actively controlled traffic in an air traffic control tower?		19.21
How many of the past 12 months have you actively controlled traffic in an air traffic control tower?		12
5. Do you have experience with any of the following electronic flight strip systems? Number of Controllers=Yes		
Advanced Electronic Flight Strip System (ORD) Electronic Flight Strip Transfer System (EFSTS) Number = Yes		2
Other *		2
6. If other, please specify		TODDS/FDM
7. Have you participated in any previous Staffed NextGen Tower evaluations?		
Yes		8

REALISM QUESTIONNAIRE DATA

	Mdn
3. On a scale of 1 to 7, with 1 indicating Not At All Realistic and 7 indicating Extremely Realistic, please rate the following:	
a. How realistic was the overall simulation experience compared to actual ATC operations? *	4.50
b. Thinking about the traffic scenarios, how representative were they of a typical workday at your facility? *	5.00
c. Thinking about the traffic scenarios, how realistic were the traffic patterns compared to actual NAS traffic? *	5.00
d. How realistic was the out-the-window view compared to an actual OTW view?	5.00
e. How realistic was the TIDS compared to an ASDE-X? *	6.50
g. How well did the simulation pilots respond to your clearances in terms of traffic movement and callbacks? *	4.00
h. How realistic was the simulated tower environment compared to actual field operations? *	4.50
4. On a scale of 1 to 7, with 1 indicating Very Ineffective and 7 indicating Very Effective, please rate the effectiveness of the training provided on each of the following systems	
a. TIDS	7.00
b. Scanning Camera on the TIDS	6.50
c. FDM	6.00
d. Auxiliary Camera Display	4.00
e. Scanning Camera on the Auxiliary Display	4.00
f. Fixed Camera on the Auxiliary Display	4.00
5. On a scale of 1 to 7, with 1 indicating Not at All and 7 indicating A Great Deal, rate the extent to which the oculometer interfered with your ATC performance?	4.50

POST-RUN QUESTIONNAIRE DATA

	No Camera No OTW	No Camera OTW	Camera No OTW	Camera OTW
	Mdn	*Mdn*	*Mdn*	*Mdn*
7. On a scale of 1 to 7, with 1 indicating Very Little and 7 indicating Very Much, please rate the degree to which the following displays or camera views helped you maintain awareness of aircraft identity during this scenario:				
a. Out-the-Window Display		6.50		6.00
b. TIDS Display	7.00	7.00	7.00	7.00
...i. Scanning Camera Picture-in- Picture (PIP)			6.00	6.00
c. Auxiliary Camera Display			5.00	4.00
...i. Scanning Camera Window			4.50	5.00
...ii. Fixed Camera Window			4.00	3.50
...iii. Panoramic Camera Window			5.00	5.00
d. FDM Display	6.00	5.00	6.00	4.00
8. On a scale of 1 to 7, with 1 indicating Very Little and 7 indicating Very Much, please rate the degree to which the following displays or camera views helped you maintain awareness of traffic location during this scenario:				
a. Out-the-Window Display		6.50		6.00
b. TIDS Display	7.00	7.00	7.00	7.00
...i. Scanning Camera PIP			5.00	6.00
c. Auxiliary Camera Display			5.00	4.50
...i. Scanning Camera Window			4.50	4.50
...ii. Fixed Camera Window			4.50	4.00
...iii. Panoramic Camera Window			5.50	5.00

	No Camera No OTW	No Camera OTW	Camera No OTW	Camera OTW
	Mdn	*Mdn*	*Mdn*	*Mdn*
d. FDM Display	5.00	5.50	4.50	3.50
9. On a scale of 1 to 7, with 1 indicating Very Little and 7 indicating Very Much, rate the degree to which each display helped predict/anticipate aircraft position during this scenario:				
a. Out-the-Window Display		6.00		6.50
b. TIDS Display	7.00	7.00	7.00	7.00
...i. Scanning Camera PIP			4.50	5.50
c. Auxiliary Camera Display			5.00	4.00
...i. Scanning Camera Window			4.00	4.00
...ii. Fixed Camera Window			4.00	3.50
...iii. Panoramic Camera Window			5.50	5.00
d. FDM Display	5.00	5.00	4.50	3.00
10. On a scale of 1 to 7 with 1 indicating Very Little and 7 indicating Very Much, rate the degree to which each display increased your ability to detect aircraft during this scenario:				
a. Out-the-Window Display		6.50		6.50
b. TIDS Display	7.00	7.00	7.00	7.00
...i. Scanning Camera PIP			6.00	5.00
c. Auxiliary Camera Display			4.00	4.00
...i. Scanning Camera Window			5.00	4.50
...ii. Fixed Camera Window			4.00	4.00
...iii. Panoramic Camera Window			5.50	5.00
d. FDM Display	5.50	5.00	5.50	3.50

	No Camera No OTW	No Camera OTW	Camera No OTW	Camera OTW
	Mdn	*Mdn*	*Mdn*	*Mdn*
11. On a scale of 1 to 7, with 1 indicating Very Little and 7 indicating Very Much, please rate the degree to which the following displays or camera views helped you maintain efficient operations during this scenario:				
a. Out-the-Window Display		6.50		6.00
b. TIDS Display	7.00	7.00	7.00	7.00
...i. Scanning Camera PIP			4.00	5.00
c. Auxiliary Camera Display			4.00	4.00
...i. Scanning Camera Window			4.00	4.00
...ii. Fixed Camera Window			4.00	4.00
...iii. Panoramic Camera Window			5.00	5.00
d. FDM Display	5.00	5.00	4.50	4.00
12. On a scale of 1 to 7, with 1 indicating Very Little and 7 indicating Very Much, please rate the degree to which the following displays or camera views helped you maintain safe operations during this scenario:				
a. Out-the-Window Display		7.00		6.50
b. TIDS Display	7.00	7.00	7.00	7.00
...i. Scanning Camera PIP			6.50	6.50
c. Auxiliary Camera Display			4.50	4.00
...i. Scanning Camera Window			5.50	4.50
...ii. Fixed Camera Window			4.50	4.00
...iii. Panoramic Camera Window			5.50	4.50
d. FDM Display	4.50	4.00	3.50	3.00

	No Camera No OTW	No Camera OTW	Camera No OTW	Camera OTW
	Mdn	*Mdn*	*Mdn*	*Mdn*
13. On a scale of 1 to 7, with 1 indicating Very Little and 7 indicating Very Much, rate the degree to which each display helped you validate or confirm potential runway incursions during this scenario:				
a. Out-the-Window Display		6.50		6.00
b. TIDS Display	7.00	7.00	7.00	7.00
...i. Scanning Camera PIP			4.00	4.00
c. Auxiliary Camera Display			4.00	4.00
...i. Scanning Camera Window			4.00	4.00
...ii. Fixed Camera Window			4.00	3.50
...iii. Panoramic Camera Window			4.50	4.00
d. FDM Display	1.50	2.50	2.00	2.03
14. On a scale of 1 to 7, with 1 indicating Very Little and 7 indicating Very Much, rate the degree to which each display helped you detect any off-nominal events during this scenario:				
a. Out-the-Window Display		6.50		6.00
b. TIDS Display	7.00	7.00	7.00	7.00
...i. Scanning Camera PIP			5.00	5.50
c. Auxiliary Camera Display			3.50	4.00
...i. Scanning Camera Window			5.00	4.00
...ii. Fixed Camera Window			3.50	3.50
...iii. Panoramic Camera Window			4.00	4.00
d. FDM Display	1.50	1.50	2.50	1.50

	No Camera No OTW	No Camera OTW	Camera No OTW	Camera OTW
	Mdn	*Mdn*	*Mdn*	*Mdn*
15. On a scale of 1 to 7, with 1. indicating Very Low and 7 indicating Very High, rate your workload during this scenario with regard to the following:				
a. Overall workload	4.50	4.00	4.00	4.00
b. Workload due to communications with pilots	3.50	4.00	4.00	3.00
c. Workload due to off-nominal events	3.00	3.00	4.00	3.00
d. Workload due to coordination with the ground/local controller	1.50	2.00	2.00	1.00
e. Workload due to overall interactions with the auxiliary camera displays			2.50	3.00
...i. Scanning			2.50	3.00
...ii. Fixed			2.50	3.00
...iii. Panoramic			1.50	2.50
f. Workload due to interactions with the Scanning Picture-in- Picture camera display			3.00	3.00
g. Workload due to toggling the fixed camera images			3.00	2.50
16. On a scale of 1 to 7, with 1 indicating Very Low and 7 indicating Very High, rate your situation awareness during this scenario with regard to the following:				
a. Overall level of situation awareness	6.50	6.50	6.00	6.00
b. Situational awareness related to communications with pilots	6.00	6.00	5.50	6.00
c. Situational awareness of off- nominal events	6.00	5.50	5.50	6.00
d. Situational awareness related to coordination with the ground/local controller	6.00	5.00	4.00	5.00
e. Situational awareness related to overall interactions with the auxiliary camera display *			4.50	4.00

	No Camera No OTW	No Camera OTW	Camera No OTW	Camera OTW
	Mdn	*Mdn*	*Mdn*	*Mdn*
...i. Scanning			4.00	5.00
...ii. Fixed			4.00	3.00
...iii. Panoramic			4.50	3.50
f. Situational awareness related to interactions with the Scanning Picture-in-Picture camera display			5.00	6.00
g. Situational awareness related to toggling the fixed camera images			4.00	3.50
17. On a scale of 1 to 7, with 1 indicating Very Little and 7 indicating Very Much, how much interaction did you have with the following software components during this scenario:				
a. The Auxiliary Camera Display			4.00	4.00
...i. Scanning Camera Window			4.00	4.00
...ii. Fixed Camera Window			3.50	3.00
...iii. Panoramic Camera Window			5.00	4.00
b. The Scanning Camera PIP			5.50	5.00
18. Modified NASA-TLX scale (ratings from 1-7 with 1 indicating Extremely Low and 7 indicating Extremely High				
a. Rate your mental demand during this scenario	3.00	3.50	4.00	4.00
b. Rate your physical demand during this scenario	1.00	2.00	3.00	2.00
c. Rate your temporal demand during this scenario	2.50	2.50	4.00	3.00

	No Camera No OTW	No Camera OTW	Camera No OTW	Camera OTW
	Mdn	*Mdn*	*Mdn*	*Mdn*
d. Rate your performance during this scenario	5.00	5.50	5.00	5.00
e. Rate your effort during this scenario.	4.00	4.50	4.00	3.00
f. Rate your frustration during this scenario.	2.00	2.00	4.00	2.00

POST RUN QUESTIONNAIRE

**n*=8 unless otherwise indicated	*N*	*Mdn*
2. On a scale of 1 to 7, with 1 indicating Very Difficult and 7 indicating Very Easy, please rate how easy it was to perform the following tasks:		
a. Select a viewing area		4.00
...i. PIP Scanning Camera		6.00
...ii. Auxiliary Scanning Camera		5.00
b. Resize a viewing area	7	5.00
...i. PIP Scanning Camera	7	6.00
...ii. Auxiliary Scanning Camera	7	6.00
c. Select a target (i.e. aircraft or vehicle)	6	6.50
...i. PIP Scanning Camera	7	4.00
...ii. Auxiliary Scanning Camera	6	4.00
d. Track an aircraft target		6.50
...i. PIP Scanning Camera		6.00
...ii. Auxiliary Scanning Camera		5.00
e. Zoom to a viewing area	7	4.00
...i. PIP Scanning Camera	7	4.00
...ii. Auxiliary Scanning Camera	6	4.50
f. Pan to a viewing area	6	3.50
...i. PIP Scanning Camera	6	4.50
...ii. Auxiliary Scanning Camera	6	4.00
g. Tilt to a viewing area	6	4.00
...i. PIP Scanning Camera	6	4.00
...ii. Auxiliary Scanning Camera	6	4.00

*n=8 unless otherwise indicated	*N*	*Mdn*
j. Determine the location of an aircraft		6.50
...i. PIP Scanning Camera		4.00
...ii. Auxiliary Scanning Camera		4.00
...iii. Fixed Camera		4.00
...iv. Panoramic Camera		4.00
k. Determine the aircraft type/company		6.50
...i. PIP Scanning Camera		6.00
...ii. Auxiliary Scanning Camera		4.00
...iii. Fixed Camera		4.50
...iv. Panoramic Camera		5.00
3. On a scale of 1 to 7, with 1 indicating Very Difficult and 7 indicating Very Easy, please rate how easy it was to perform the following tasks:		
a. Select a viewing area		4.50
...i. PIP Scanning Camera	7	6.00
...ii. Auxiliary Scanning Camera	7	4.00
b. Resize a viewing area	7	4.00
...i. PIP Scanning Camera	7	5.00
...ii. Auxiliary Scanning Camera	6	4.00
c. Select a target (i.e. aircraft or vehicle)	6	4.00
...i. PIP Scanning Camera	6	4.00
...ii. Auxiliary Scanning Camera	6	4.00
d. Track an aircraft target		6.00
...i. PIP Scanning Camera		6.50

**n*=8 unless otherwise indicated	*N*	*Mdn*
...ii. Auxiliary Scanning Camera	7	5.00
e. Zoom to a viewing area	7	4.00
...i. PIP Scanning Camera		5.00
...ii. Auxiliary Scanning Camera	6	4.00
f. Pan to a viewing area	6	3.00
...i. PIP Scanning Camera	7	4.00
...ii. Auxiliary Scanning Camera	6	3.50
g. Tilt to a viewing area	5	3.00
...i. PIP Scanning Camera	6	3.00
...ii. Auxiliary Scanning Camera	6	3.00
j. Determine the location of an aircraft		6.00
...i. PIP Scanning Camera		4.50
...ii. Auxiliary Scanning Camera	7	4.00
...iii. Fixed Camera		4.00
...iv. Panoramic Camera		4.50
k. Determine the aircraft type/company		7.00
...i. PIP Scanning Camera		6.50
...ii. Auxiliary Scanning Camera	7	5.00
...iii. Fixed Camera		6.00
...iv. Panoramic Camera		6.50
4. On a scale of 1 to 7, with 1 indicating Very Inadequate and 7 indicating Very Adequate, please rate the adequacy of the following:		
a. The ability to track a target		5.00

**n*=8 unless otherwise indicated	*N*	*Mdn*
...i. PIP Scanning Camera		5.00
...ii. Auxiliary Scanning Camera		4.00
b. The overall automatic camera scanning functionality		5.50
...i. PIP Scanning Camera		6.00
...ii. Auxiliary Scanning Camera		4.00
c. The ability to detect aircraft non-conformance		5.00
...i. PIP Scanning Camera		4.00
...ii. Auxiliary Scanning Camera		3.50
...iii. Fixed Camera		3.50
...iv. Panoramic Camera		4.50
d. The ability to maintain overall situation awareness		5.50
...i. PIP Scanning Camera		4.50
...ii. Auxiliary Scanning Camera		4.00
...iii. Fixed Camera		4.00
...iv. Panoramic Camera *		5.00
e. The pan, tilt, and zoom gauges on the Auxiliary Scanning Camera	6	3.50
f. The field-of-view of the Panoramic Camera View		3.50
g. The placement of the monitors		5.00
h. The size of the Fixed Camera window		5.50
i. The size of the Auxiliary Scanning Camera window		4.50
j. The size of the PIP Scanning Camera Window		5.50
k. The auto-zoom capability of the Scanning Cameras	7	4.00

**n*=8 unless otherwise indicated	*N*	*Mdn*
l. The auto-centering capability of the Scanning Camera	7	4.00
m. The camera automation for alerts	6	6.00
5. On a scale of 1 to 7, with 1 indicating Completely Unnecessary and 7 indicating Completely Necessary, please rate the following:		
a. The overall benefit of the cameras for supplemental SNT operations		4.50
...i. of the PIP Camera Display		5.00
...ii. of the Auxiliary Camera Display		4.00
b. The overall benefit of the cameras for contingency SNT operations		5.50
...i. of the PIP Camera Display		6.00
...ii. of the Auxiliary Camera Display		4.00
6. On a scale of 1 to 7, with 1 indicating Completely Unacceptable and 7 indicating Completely Acceptable, please rate the following:		
a. The overall camera presentation		5.00
...i. on the PIP Camera Display		5.00
...ii. on the Auxiliary Camera Display		4.50
b. The overall camera resolution		5.00
...i. of the PIP Camera Display		5.50
...ii. of the Auxiliary Camera Display		5.00
c. The overall camera functionality		5.00
...i. on the PIP Camera Display		5.00
...ii. on the Auxiliary Camera Display		4.00
d. The alerting capability for off-nominal events		6.00
...i. on the PIP Camera Display		5.50

**n*=8 unless otherwise indicated	*N*	*Mdn*
...ii. on the Auxiliary Camera Display		4.50
e. The overall camera lag time		5.00
...i. on the PIP Camera Display		5.50
...ii. on the Auxiliary Camera Display		4.00
f. The layout of the inset windows on the Auxiliary Camera Display		5.00
g. The size of the Auxiliary Camera Display		6.00
h. The readability of text on the Auxiliary Camera Display	7	5.00
7. On a scale of 1 to 7, with 1 indicating Completely Unnecessary and 7 indicating Essential, please rate the importance of depicting the following information on a camera display in a Supplemental SNT environment:		
a. Panoramic view of entire airport		6.50
b. The approach area		6.00
c. Runway intersections		5.00
d. Blocked line-of-sight areas		6.00
e. Areas or aircraft under alert conditions		5.00
f. Controller-selected areas		7.00
8. Please list any other areas that you believe might need to be depicted on a camera display in the Supplemental SNT environment:		
9. On a scale of 1 to 7, with 1 indicating Completely Unnecessary and 7 indicating Essential, please rate the importance of depicting the following information on a camera display in a Contingency SNT environment: *		
a. Panoramic view of entire airport		7.00
b. The approach area		5.50
c. Runway intersections		5.50
d. Blocked line-of-sight areas	7	5.00

**n*=8 unless otherwise indicated	*N*	*Mdn*
e. Areas or aircraft under alert conditions		6.00
f. Controller-selected areas		7.00
10. Please list any other areas that you believe might need to be depicted on a camera displays in the Contingency SNT environment:		
11. How would you use the camera displays in a Supplemental SNT environment? (For example, binoculars view, line-of-sight areas, areas of alert, etc.)		
12. How would you use the camera displays in a Contingency SNT environment? (For example, binoculars view, line-of-sight areas, areas of alert, etc.)		
13. Please enter any additional comments regarding the camera displays. Are there any features that need to be added, modified, or removed?		
14. On a scale of 1 to 7, with 1 indicating Completely Disagree and 7 indicating Completely Agree, please rate the following: *		
a. Supplemental SNT will be beneficial for Tower Controllers		7.00
b. Supplemental SNT will be beneficial for the NAS as a whole		7.00
c. Contingency SNT will be beneficial for Tower Controllers		5.50
d. Contingency SNT will be beneficial for the NAS as a whole		6.00
15. Please enter any comments regarding your view of the Supplemental SNT concept:		
16. Please enter any comments regarding your view of the Contingency SNT concept:		
17. When it was available, what percentage of the time did you use the out-the-window view to help maintain situation awareness?		
18. What percentage of the time did you use the TIDS to help maintain situation awareness? *		
19. If you could only have either the out-the-window (OTW) view or the TIDS to help you to maintain your situation awareness, which one would you keep? *		
20. On a scale of 1 to 7, with 1 indicating Very Difficult and 7 indicating Very Easy, please rate how easy it was to perform the following tasks using the TIDS:		

**n*=8 unless otherwise indicated	*N*	*Mdn*
*		
a. Select a data block		6.50
b. Deselect a data block		6.50
c. Move a data block	5	4.00
d. Maintain data block separation	6	3.50
e. Detect aircraft location/position		6.50
f. Determine aircraft type		5.50
g. Determine aircraft weight class		5.50
h. Determine aircraft airborne/ground status		5.00
i. Find necessary flight information		4.00
j. Maintain Situation Awareness		7.00
k. Create a PiP window to view other areas of the airport (approach, bridge, etc. - not the camera window)		6.00
l. Manipulate (resize, move, etc) the PiP window (not the camera window)	7	6.00
21. On a scale of 1 to 7, with 1 indicating Very Inadequate and 7 indicating Very Adequate, please rate the adequacy of the following with regards to the TIDS: *		
a. The size of the overall display		7.00
b. The size of the icons, text, and data blocks		6.50
c. The picture-in-picture (PIP) capability		6.50
d. The color schema of the icons and text		7.00
e. The data block time sharing		6.50
f. The data block presentation		6.50
22. Please enter any additional comments regarding the TIDS. Are there any features that you believe need to be added, modified, or removed?		

**n*=8 unless otherwise indicated	*N*	*Mdn*
Please answer the following questions as they relate to the functionality of the FDM Display.		
23. On a scale of 1 to 7, with 1 indicating Very Difficult and 7 indicating Very Easy, please rate how easy it was to perform the following tasks using the FDM display: *		
a. Select a flight strip		6.50
b. Deselect a flight strip		5.50
c. Undo an action/correct an error	7	5.00
d. Determine aircraft location		6.00
e. Transfer flight information		7.00
f. Edit flight information	7	5.00
g. Find flight information		6.00
h. Manage flight strips		6.50
i. Retrieve a flight strip	7	7.00
24. On a scale of 1 to 7, with 1 indicating Very Inadequate and 7 indicating Very Adequate, please rate the adequacy of the following with regards to the FDM display:		
a. The strip bay configuration		5.00
b. The information presentation		5.50
c. The type of information presented		5.50
d. The size of the display		6.50
e. The readability/legibility of the text		6.50